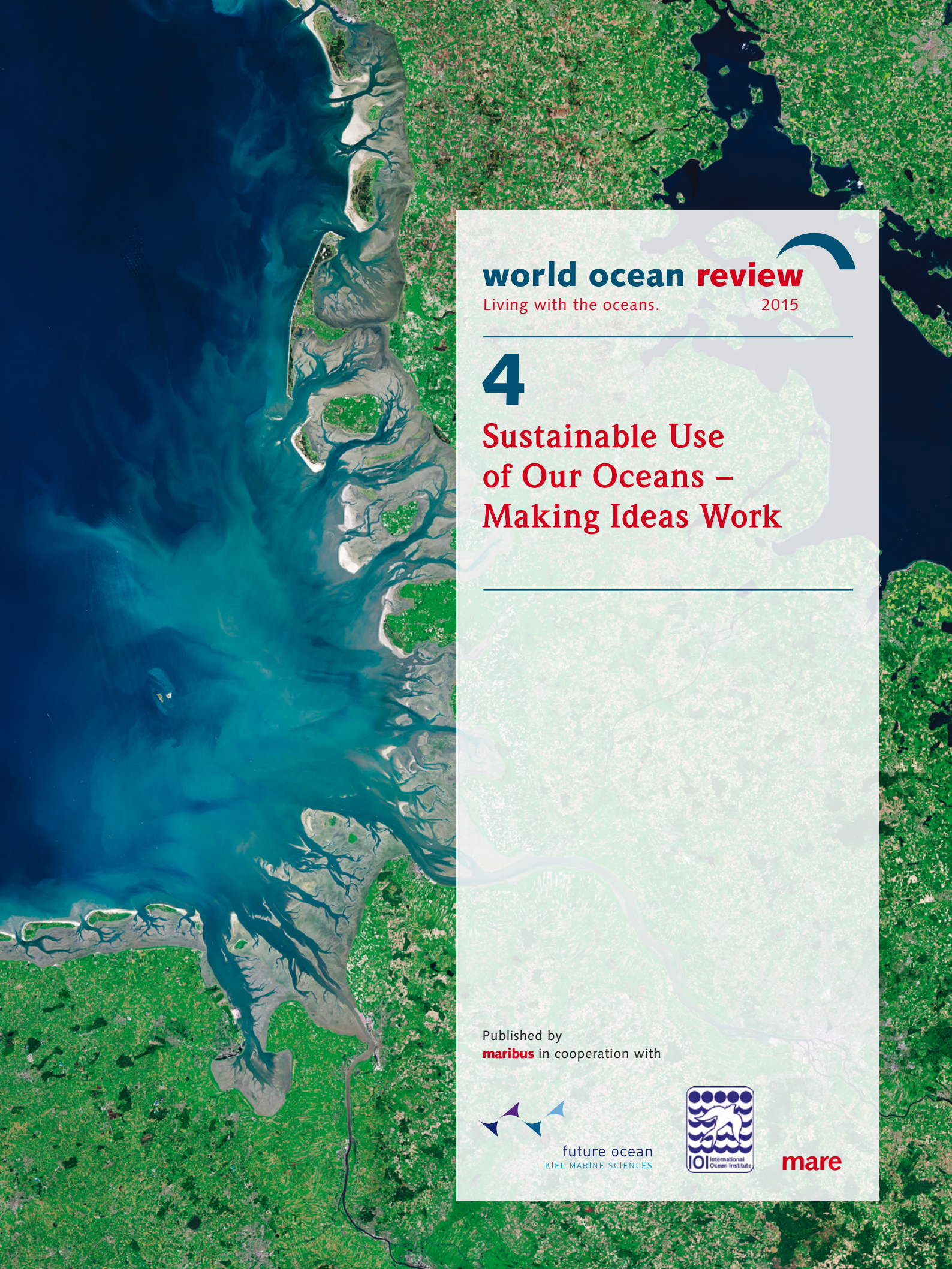


world ocean review

Living with the oceans. 2015

4

Sustainable Use of Our Oceans – Making Ideas Work

Published by
maribus in cooperation with

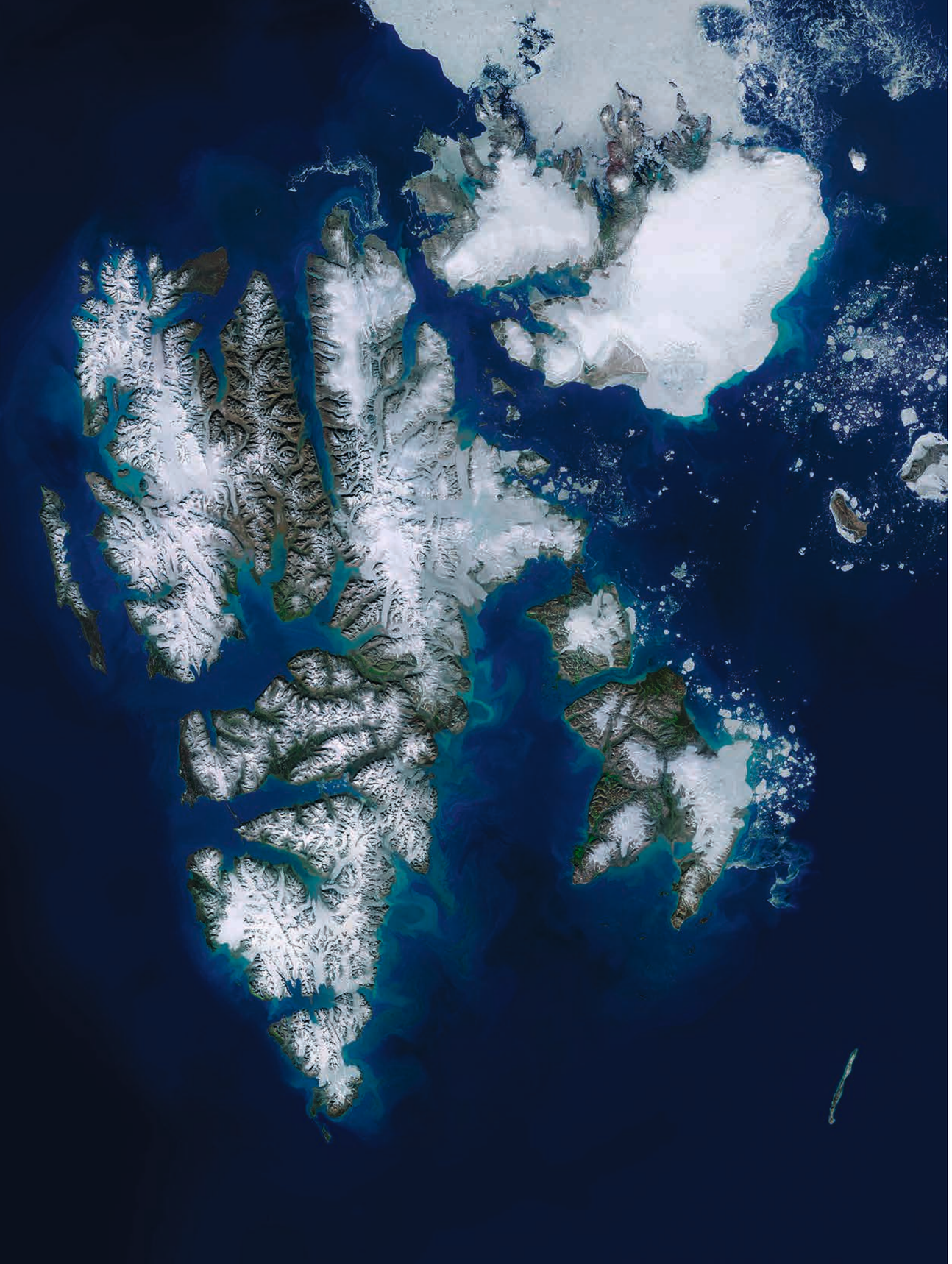
future ocean
KIEL MARINE SCIENCES

IOI International Ocean Institute

mare

world ocean review

Living with the oceans. 2015



4

Sustainable Use of Our Oceans – Making Ideas Work

Preface

Time brings change. In our fast-moving age, the Earth, and therefore also Nature and our society, are changing ever more rapidly. With high population growth and the progressive diversification of labour, we humans are changing the face of our planet to an unprecedented extent.

Some of the greatest challenges result from growing complexity, interconnectedness and linkages across the globe: examples are the increasing integration of international financial markets and the economic interdependence of consumer and producer societies. In a globalized world, comprehending all that happens in politics, the economy and the cultural sphere has become an ever more difficult task.

Our scientific knowledge, too, has grown apace. It has become more diverse and multifaceted, creating something of a barrier to understanding and making the lessons to be learned from science less accessible. This applies especially to our oceans. Over recent decades, we have learned, for example, that chemical, biological and physical processes in the marine environment influence each other and cannot be viewed in isolation, requiring a more integrated approach to our interpretation of scientific data and showing that there are no simple answers to the multitude of questions arising in modern marine research. Indeed, as we increasingly recognize that marine ecosystems are worth protecting, many questions and expectations arise. We must begin, therefore, by being mindful of the essentials: by establishing clarity on the concepts and terminology and how to communicate them to a wider public, and being clear about the fundamental principles guiding our actions.

One of the most important and most frequently asked questions – and also one of the most difficult to answer – is this: what does "sustainability" mean? Sustainability embodies the approach that we must take to our future management of our oceans. But it is not only used by environmentalists and peace researchers. It is increasingly claimed by business as well. The concept of sustainability not only informs the debate about making sparing use of the seas' resources for their own sake; it is also part of the numerous polemics from businesses in their roles as energy suppliers and food producers.

This fourth *World Ocean Review* shows how the concept of sustainability came into being, how and why it is so often used, and how it should guide our actions in future. In this ever more complex and globalized world, it shows that ultimately, policy-makers, acting on behalf of the public as the source of their legitimation, but also citizens themselves must take responsibility. I hope that this review will bring this assumption of responsibility and hence the protection of our seas a little closer for everyone.

Nikolaus Gelpke
maribus gGmbH Managing Director, mareverlag publisher and IOI President

We humans have utilized the services provided by the seas since time immemorial while attempting, at the same time, to avoid the dangers that they pose. We seek proximity to the sea, for our coastlines offer many benefits to those who live there. With a rapid growing population, however, many of us are concerned about the future of our oceans and coasts. How can conservation and use be reconciled? Which criteria should be applied to assess potential development pathways towards sustainable use of the marine environment?

These questions arise with particular urgency in relation to fishing and the many other claims on the diverse resources found in the oceans, marginal seas and coastal regions. How much ocean pollution is acceptable? What form of compensation arrangements should be established between winners and losers? Philosophy and environmental ethics help us to structure these questions and address them in light of fundamental issues of sustainability. It is this discourse which provides guidance as we develop solutions to distribution issues, taking account of intergenerational justice and global responsibility.

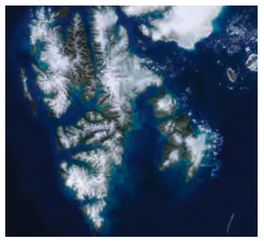
This fourth *World Ocean Review* focuses on sustainability. It offers insights into the economic value of the environment and explains sustainable development concepts that can be applied to the oceans. It also offers an overview of the ecosystem services that our seas provide. In recent years, we have come to recognize that the resources of our Earth and its oceans are finite. This means that we must identify and accept planetary and oceanic boundaries and factor them into human development.

How are our seas faring today? The first *World Ocean Review* provided a full and detailed answer to this question, and the key aspects are reprised in this latest edition. Poverty reduction, education and a well-functioning social system are essential prerequisites for sustainable development. Given that our world consists mainly of ocean, global governance regimes – not only the law of the sea – have an important role to play. The United Nations has numerous organizations and agencies whose mandate extends to the marine environment. Are there too many of them? Would more inter-agency cooperation be beneficial?

In autumn 2015, the United Nations adopted the new Sustainable Development Goals (SDGs). For the first time, marine conservation is now a global goal in its own right. This creates visibility and political capital for the oceans. Movement towards the sustainable use of the oceans is possible, and good progress is already being made in some areas.

A global sustainable development agenda must take account of five dimensions: human dignity, the environment, prosperity, peace and cooperation. The world's oceans have a key role to play in all of them. In that spirit, I wish you an inspiring and thought-provoking read.

Prof. Dr. Martin Visbeck
Spokesperson of the Cluster of Excellence "The Future Ocean"



1 Concepts for a better world

> Prudent and sustainable use of nature's resources has yet to become a reality. Past approaches have failed because the concept of "sustainability" is so ill-defined. Moreover, sustainability can only be accomplished if the complex linkages within the natural world are valued more accurately. For the future it is therefore vital to improve our understanding of the diverse services of ecosystems and to put a comprehensive conception of sustainability into practice.

What is sustainability?

> The concept of "sustainability" comes from forestry and originally meant something like: using natural resources mindfully so that the supply never runs out. Today, however, the concept is ill-defined; firstly because there are various theories of sustainability and secondly because the word has passed into inflationary use. For that reason scientists now debate what is actually meant by "sustainability" and seek to formulate concrete guidelines for sustainable living and economic activity.

A tricky concept

Nowadays the concept of "sustainability" is a staple of any public debate and is used in an inflationary way. Playing on the positive connotations of the word "sustainability" – much like "peace", "justice" and "conservation" – people tend to use it in every possible context. Industry talks about "sustainable production" and financial services providers offer "sustainable performance". Consumers are urged to "eat and drink sustainably"; music classes support "sustainable child development" and even a warm-water bathing day for senior citizens at a public pool is advertised as "sustainable". Everybody understands "sustainability" to mean something slightly different. The concept tends to be more confusing than clarifying. Depending on the given definition, project or context it takes on a different meaning. But the current inflationary use of the term is not solely to blame for this baffling ambiguity; the fact is, the concept is indeed a blend of different factors. Sustainability is a complex matter. Economic development models, the world food supply, nature conservation, poverty reduction or distributive justice – all these aspects play a part in the sustainability debate. Looking back into the past, however, it is evident that the individual themes were often considered in isolation from one another and studied separately. Depending on the historical situation, certain questions took precedence, and others were put on hold until they in turn had become urgent.

Experts today endeavour to frame plausible theories and models in order to enhance the understanding of all the elements that comprise sustainability. The main challenge for the future is to put the broadly accepted insights of sustainability theorists into practice in concrete societal, political or economic models.

1.1 > The concept of "sustainable" silviculture was introduced in 1713 by the Saxonian chief mining official Hans Carl von Carlowitz in his treatise *Sylvicultura oeconomica*, in which he advocated prudent management of forest resources.

Fear of timber scarcity

The expression "sustainable" or "sustainability" came into use in German silvicultural theory in the 18th century. Back in 1713 the chief mining official Hans Carl von Carlowitz, from Freiberg in what was then the Principality of Saxony, published the forestry treatise *Sylvicultura oeconomica*, in which the principle of "continuously enduring and sustainable use" was discussed for the first time. Von Carlowitz coined the term at a time when many parts of Europe were in need of vast quantities of wood for mining and ore-smelting. Gradually the environs of many mining towns were becoming deforested. Wood shortages were an imminent threat. Even at the start of the 18th century, wood was having to be shipped from far away by river. Von Carlowitz warned that, without wood, people would "suffer great hardship". In his *Sylvicultura oeconomica* he called for the forests to be conserved. People, he wrote, should save wood, conserve forests by sowing and planting trees, and seek "surrogata" or alternatives to wood. All in all, people should only harvest as much wood as could regrow.

The aim of forest management was to achieve the greatest possible wood harvest sustainably – in other words, consistently over time – without overexploiting the forest. Thus, 300 years ago, von Carlowitz was voicing demands which are still crucial to the current sustainability debate. Then, however, the focus was on economic considerations rather than nature and forest conservation per se. That was equally apparent from the composition of the forests, and what was considered sustainable at the time: they tended to be monocultures of tree species of interest to the wood industry rather than near-natural forests. Since the concept of sustainability was originally clearly and narrowly defined, it provided a basis for deriving binding rules. For every tree species, prescribed felling rates were defined, i.e. annual maximum quantities of wood that were permissible to cut in a section of forest.

1.2 > Silviculturists in the state of Minnesota, USA at the end of the 19th century. Wood was in particular demand as a raw material at the time, and vast quantities of it were required for housebuilding in the growing towns.

Too many people – too little food

Not just in Germany but throughout Europe, scholars in the eighteenth century were getting to grips with the finite nature of natural resources, although in this context – unlike in the work of von Carlowitz – there was no discussion of sustainability. An important aspect was how to supply foodstuffs to the growing population. Today it is estimated that the population of Europe as a whole grew from 140 million to 266 million between 1750 and 1850. In England alone, the number of inhabitants swelled from around 7 to 20 million people during the same period.

The British economist Thomas Robert Malthus warned that food production would not be able to keep pace with population growth in future. And if the plight of the poor improved, he wrote, this would lead to further population growth – and hence to a food crisis. Ultimately, the result would be a worsening of overall poverty. One solution, Malthus and others seemed to think, would be to maintain the population figure at a constant level. A few years earlier, scholars like the North German lawyer, Justus Möser, had already argued against smallpox vaccination on population policy grounds. The vaccination, Möser warned, would reduce child mortality so greatly that "the world would become too small for all the progeny of mankind".

The doom-laden fears of scholars like Malthus and Möser did not come to pass. Before population growth in Europe could lead to a large-scale food shortage, the problem was solved by a natural scientist: in the mid-19th century, the German chemist Justus Liebig developed artificial fertilizer, paving the way for a huge increase in the productivity of arable farmland. Just as his precursor von Carlowitz did for forestry, Liebig strove to achieve persistently high yields in agriculture whilst endeavouring not to deplete soil fertility.

Environmental degradation caused by the Industrial Revolution

Thanks to Liebig's invention, the kind of food shortage that Malthus had prophesied for the future never came to pass. On the contrary, the topic that captured the atten-

1.3 > Back in 1892 the richly forested Adirondack Park in New York State was designated a National Park by the US authorities. With an area of 24 000 km² it is almost as large as the island of Sicily.

tion of thinkers and scientists was degradation of the natural environment because, in the late eighteenth and the first half of the nineteenth centuries, Europe was overtaken by the Industrial Revolution: the slow and deep-seated transformation of an agricultural into an industrial society. The world was radically transformed by coal mining, metal smelting, the growth of towns and the construction of barrage dams, highways and railways. One who criticized the devastating impacts of this industrial growth was the US statesman and scholar George Perkins Marsh, who toured Europe in the 1850s and was ambassador at the Italian court in Rome between 1861 and 1882. In many of the locations he visited, he observed how humans were changing and to some extent destroying nature. In 1874 he published his most important work, *Man and Nature: The Earth as Modified by Human Action*, in which he described his observations. Marsh's ideal was the village community which conserves nature in the long term and uses its resources mindfully. He warned that humans were in the process of rendering the Earth, the home of humankind, unfit for habitation. People needed to protect nature out of "enlightened self-interest", he argued. But Marsh also emphasized that it was possible to use natural resources rationally. People have a right to use nature's assets, he stated, but not to abuse them.

Marsh's theories and his drastic descriptions of environmental degradation in Europe had the most momentous impact in his country of birth, the USA. In order to prevent deforestation on a European scale, the decision was made to conserve forests. Initially, protection was given just to some areas in isolation. The year 1892, for example, – 10 years after Marsh's death – saw the founding of the richly forested Adirondack Park in the state of New York. Covering an area of 24 000 km², this National Park, the largest in the USA today, is almost as large as the island of Sicily. At the beginning of the twentieth century, the authorities finally came round to safeguarding forests throughout the country from overexploitation. It was in 1905 that the United States Forest Service was founded, a forest authority whose first Chief was Gifford Pinchot. Pinchot, a forest scientist and politician, was inspired by

1.4 > The US scholar George Perkins Marsh is acknowledged as one of the forefathers of the environmental movement. In the mid-19th century on a tour of Europe he experienced how nature was being destroyed. His drastic descriptions of this overexploitation contributed to the introduction of sustainable forest management in the USA.

Marsh's teachings. He established sustainable forest use in the USA, just as had been advocated by von Carlowitz almost 200 years previously.

Prosperity rather than sustainability?

Apart from a few positive examples, however, the idea of making prudent use of nature stubbornly failed to take off. For one thing, periods of severe deprivation during two World Wars led policymakers in Western industrialized countries to pursue one goal above all else in the mid-20th century: to generate prosperity for all and, through constant economic growth, to overcome absolute poverty and alleviate class disparities. Thus, the dualism of economic growth and sustainability was preordained.

At the beginning of the 1960s, however, there was mounting criticism of this naïve faith in growth and progress. The damage caused by unchecked economic growth took on increasingly vast dimensions. Soils and rivers were being poisoned. Smog was forming in many urban centres from the emissions of cars, factories and power

plants. Children in particular suffered from respiratory illnesses. Sulphur dioxide emissions from power plants and car engines led to the phenomenon of "acid rain", which caused trees and entire swathes of forest to die off. Environmental conservationists talked about "forest death".

In the 1970s, the concept of "sustainability" then underwent a renaissance. It was now defined more broadly than before. Advocates of sustainability criticized the established economic models which insisted that economic growth was an ongoing necessity. In 1972 the Club of Rome published its highly respected study, *The Limits to Growth*, which mentioned a "sustainable global system" for the first time. In its report, the Club of Rome warned against the consequences of overexploitation. It developed a theory which stated that every phase of strong economic growth would inevitably be followed by a major collapse of the system. Resource scarcity and environmental pollution would turn into severe crises and reduce people to living in the most basic conditions well before the year 2100.

Today opponents of this gloomy vision of the future continually point out that there was no shortage of non-renewable resources after all, because new sources of raw materials have constantly been discovered and exploited. On the other hand, many experts today warn about supply bottlenecks for certain metals either because they only exist in small quantities or because individual states have a monopoly over them. Moreover, they say, resource extraction continues to cause the destruction of natural areas. In their view, the Club of Rome's forebodings are perfectly justified.

The Club of Rome's assumption that environmental pollution would definitely increase in line with economic growth has been considered by some critics to have been refuted in the meantime. Some economists asserted that growing prosperity would be accompanied by greater investment in environmental protection. Many European countries and other industrialized countries around the world did indeed succeed in considerably reducing environmental pollution by means of technical measures like sewage treatment plants and filters in power stations and cars – despite the continuation of economic growth. In the light of environmental pollution and degradation on a massive scale in emerging economies like Brazil, China and India, today the warnings of the Club of Rome take on renewed importance. Contemporary China in particular is a textbook example of the environmental destruction and ecological costs that go hand in hand with unrestrained economic growth. The debate between the critics and proponents of growth continues to this day.

1.5 > In 1966 Essen was the first city in Germany to introduce driving prohibitions in order to reduce the pollution caused by smog. But only when power stations and industrial plants were fitted with emissions filters in the 1980s did air quality improve noticeably.

Club of Rome
The Club of Rome is an international non-governmental organization and expert body which was founded in 1968 by leading industrialists, engineers, business experts and academics in order to analyse the negative consequences of economic growth and to develop solutions.

Same rules for all?

From the 1960s onwards, the "underdevelopment" of the so-called Third World was another much-discussed topic. On the one hand there were economists who saw the economic growth and business model of the industrialized nations as an example worth emulating. In their view the national economies of the Third World countries should match, as rapidly as possible, the industrialized countries' standard of development through "catch-up" industrialization and modernization. Support should be provided to them in the form of development assistance. For this, the prototype was the U.S. aid for reconstruction in Western Europe in the immediate post-war period, which had been organized under the **Marshall Plan**. But this policy did not work well everywhere. Moreover, it did not guarantee universal development or that the entire population of a country would share in the resulting prosperity. Therefore, alongside these more capitalist Western models, other models of development emerged. These were overtly aimed at greater ownership by developing countries of their development processes, and at a more socialist policy of redistribution from the top down, for instance by means of land reforms. The aim of development in such models was not primarily higher consumption of goods but was rather oriented towards aspects like education, health or public participation in policy-making processes.

One milestone was the "eco-development" approach of the Dag Hammarskjöld Foundation in the 1970s. This Foundation was named after the Swedish diplomat and United Nations Secretary-General Dag Hammarskjöld, who had lost his life in a plane crash in 1961. The Foundation has its headquarters in the Swedish city of Uppsala and has continued to organize international conferences and seminars at which experts debate themes of policy such as security, democracy and development. At that time the Dag Hammarskjöld Foundation proposed guidelines on the future of developing countries, which comprised the following aspects:

- Satisfaction of basic needs largely on the basis of own resources;
- Not a copy of the Western lifestyle and pattern of consumption;
- Conservation of the environment;
- Respect for cultural difference and local traditions;
- Solidarity with future generations;
- Use of technologies adapted to local conditions;
- Participation of all population groups and particularly of women in societal and political decisions;
- Family planning;
- Some decoupling from the global market and development of local markets;
- Orientation to religious and cultural traditions;
- No admittance to the military power blocks of NATO (North Atlantic Treaty Organization) and the **Warsaw Pact**.

These early guidelines already cover key elements of the current sustainability debate.

Far more than silviculture and pollution control

While sustainability was originally applied to forestry alone, this was later joined by aspects like population growth, food, and environmental protection. Since the 1970s, aspects of society have increasingly come under the spotlight of the sustainability debate – for instance, the question of how different stakeholder groups can participate in societal and political decisions, or to what extent people today are responsible for the well-being of future generations. Against this backdrop, in 1980 the United Nations (UN) convened the World Commission on Environment and Development (WCED). It was tasked with finding ways to achieve several major objectives simultaneously, namely:

- to fight poverty in developing countries;
- to support developing countries in development in keeping with their traditions;
- to master environmental challenges;
- to level out the contrast between Western market economics and state socialism.

In 1987 the Commission presented its report, which was named the Brundtland Report after the Commission's chairwoman, the then Norwegian Prime Minister, Gro Harlem Brundtland. Its underlying idea was that the satisfaction of basic human needs should have priority over all other objectives. This "basic needs" approach was also taken into the definition of sustainability used in the WCED report, which read: "Sustainable development is

development that meets the needs of the present without compromising the ability of future generations to meet their own needs." No definition of sustainability has been quoted as frequently as this one. This wording contains the important demand that meeting human needs should be kept within the carrying capacity of the natural environment.

The Commission chose the phrasing "sustainable development" at least partly in an effort to pull together the different and in some cases competing objectives of environmental protection, poverty reduction and economic growth. Its use of this definition was an attempt to integrate some of the divergent ideas on the pathways that developing countries might take in future. The phrasing "sustainable development" was intended to help:

- to take account of the idea of the developing countries' ownership of processes without veering too far towards socialist ideals;
- to draw attention to the ecological limits to growth;
- not to lose sight of the old UN objective of fighting poverty;
- not to fundamentally challenge Western lifestyles;
- to address the challenge of population growth.

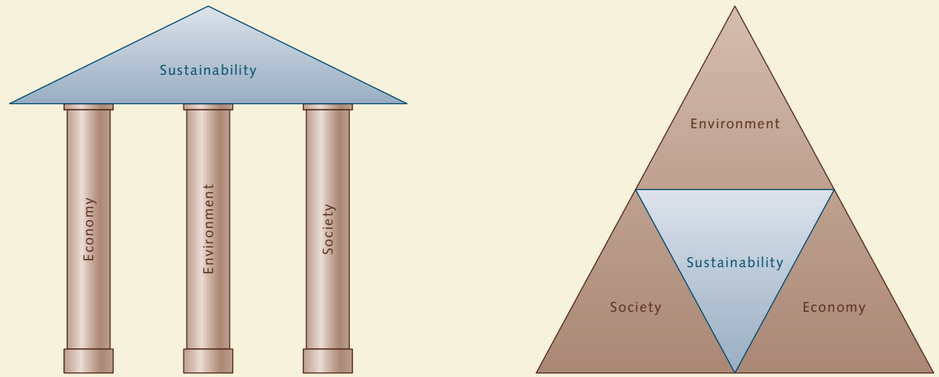
All in all, the Commission wished to define the lowest common denominator of sustainability that all its members could accept. The result was a compromise formula. A further aim of the WCED report was to bring the theme of sustainability into the public sphere. That was accomplished. The report was quite catalytic in sparking a new debate about the meaning of sustainability. What it did not provide were concrete directions for political intervention. The problem with the concept of "sustainable development" and the entire WCED report is that the wording of the definition was a compromise solution which left it open to completely different interpretations by different stakeholder groups, by politicians or by industry. Hence, the WCED report contains no systematic conception of sustainability. This is a key reason why the sustainability concept has remained so vague in the political discourse until now.

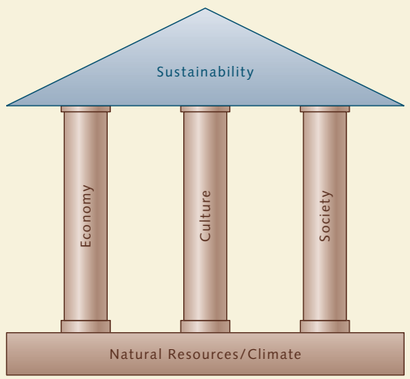
Following the publication of the WCED report, many countries embraced the idea that sustainability could be achieved by striving for the objectives framed by the Commission – poverty reduction, equitable economic growth and environmental protection – in equal measure. Taking that as a basis, theorists derived what is known as the "three pillars" model. According to this model, sustainability rests evenly on the three pillars of the environment, the economy and society, all three of which rank equally in stature. However no clear verdict is given as to whether this equal ranking is the case already, or whether it first has to be accomplished. Critics also object that the sustainability concept incorporates a normative dimension. In their view, sustainability is more than a philosophical theoretical model because ultimately, such a theory ought to make it possible to derive clear directions for action and to implement appropriate measures.

Responsibility for posterity

Making mindful use of resources over the long term to ensure that they will still be available in future is one of the pivotal ideas of sustainability. So sustainability ties in very closely with the responsibility of generations living today for the future. How far this responsibility extends has long been a matter of contention. In the 1970s, a few scientists defended the view that the generation living in the present day had absolutely no responsibility for those born later. The argument was as follows: unborn persons do not exist, are not therefore legal entities and thus cannot have rights of any kind whatsoever. On that basis, the living have no obligations towards the unborn. Today, however, this extreme perspective has few if any adherents. The very fact that future persons will have rights, the critics contend, is sufficient to permit obligations to be derived for people alive today. These obligations would not relate to particular unborn individuals but in a general way to generations of human beings living in the future. It follows that intergenerational distributive justice is an essential component of sustainable development. What legacy, or how much present-day humankind should leave for posterity, is nevertheless a debatable issue.

The classic and the extended "three pillars" model





1.6 > In the classic three pillars model, the environment, the economy and society are represented as three columns of equal stature supporting sustainability. The aim of this model, developed at the end of the 1990s, was to pave the way for sustainable development. Its underlying assumption is that economic, social and environmental concerns are interconnected and form an indivisible whole for the purposes of sustainable development. One refinement is known as the weighted three pillars model. In order to underscore the great importance of the environment, in this scheme it is represented as a foundation, formed by two factors: natural resources and the climate. Resting on this foundation are the pillars of the economy, society and – a new addition – culture. In the past 20 years, numerous other modifications of the three pillars model have been developed. One criticism levelled is that the classic version shows the environment, the economy and society as having equal standing, but does not make this a reality. Even now, the critics point out, in many cases economic concerns still take precedence over environmental or social aspects.

Quest for the equitable standard

There are many possible answers to the question of what obligations people living today have towards generations yet to come – depending on the chosen reference standard. For example, scientists make a distinction between the comparative versus the absolute standard. According to the comparative-standard model, people of future generations should be no worse off overall than the people alive today. But that immediately raises the question of whose living standards will be used for comparison – those of people in the industrialized countries or in developing countries? People's living standards can differ substantially even within the industrialized countries or emerging economies themselves. So defining a single global comparative standard is very difficult, as every basis for comparison seems arbitrary.

The absolute standard, on the other hand, stipulates minimum requirements which are fundamental elements of a life in human dignity. This absolute standard should be valid for all human beings without distinction; that includes those still to be born. Nevertheless, an absolute standard that only requires basic needs to be met is quite a low standard.

Today's reality is that a plausible absolute standard for all does not yet exist. After all, millions of people worldwide are still living in conditions of severe hardship, lacking food, clean drinking water or access to education. This realization can cause an over-emphasis on combating poverty through economic growth in emerging economies and developing countries, which detracts from the importance of conserving natural resources over the long term as a policy of sustainability would demand.

Today the prevailing opinion among sustainability theorists is that neither the comparative nor the absolute standard alone is sufficient as a yardstick for sustainability models, for in reality living conditions around the world are just too disparate at the moment. Nor do the experts see any reason to believe that in the medium term it will be possible to raise living standards in poor developing countries, such as Bangladesh for instance, to the same level as rich industrialized nations like Switzerland. It is therefore more pragmatic, they say, to define regionally differentiated standards. Thus, it would make sense to work towards one good, absolute standard for the developing countries and emerging economies, on the one hand; over and above this, on the other hand, different comparative standards are practicable for more highly developed regions and may vary from country to country or region to region.

1.7 > A slum in Dhaka, the capital of Bangladesh. Millions of people in the world live without clean water, sanitation or access to education.

This does not in any way mean that living conditions in the given regions are expected to stay the same forever. Modern sustainability models are very much geared towards reducing absolute and extreme poverty, as well as tackling the extreme disparities between the rich and the poor. A distinction needs to be made between these two goals. For as the example of China shows, it is possible for poverty in a country to lessen generally even though major disparities in income and wealth exist. Poverty in China's rural regions is receding whilst at the same time a prosperous middle class is emerging in the metropolitan centres with significantly higher incomes than the rural population.

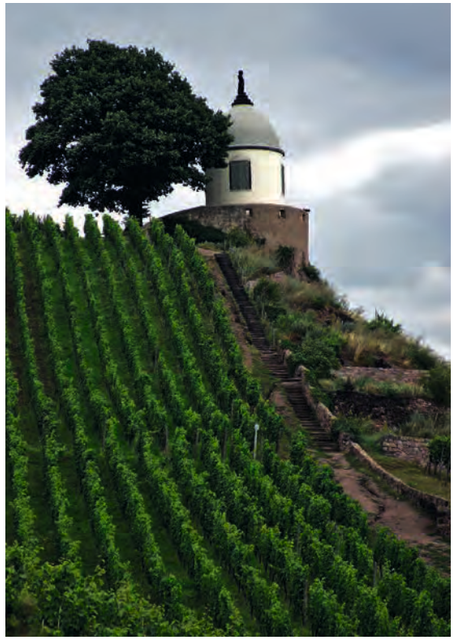
Sustainability theorists advocate reducing absolute poverty first and foremost, arguing that that is the paramount goal. They accept that some responsibility must be taken for the future, but responsibility for the present is their most immediate concern. To concentrate on the future while ignoring present-day hardship, they say, is to set the wrong priorities. So far, theorists are still at odds over the extent to which economic inequality can be permitted to exist at all.

The great goal: a life worth living

As an answer to the question of what constitutes a life of human dignity, the "basic needs" approach has been cited since the 1980s. However, this comprises only the absolute essentials of survival, particularly food, clothing and shelter. Far more ambitious is the capabilities approach which was developed around ten years ago by the US philosopher Martha Nussbaum. This contains a list of capabilities which are said to enable anybody to live a life according to their own ideas. The list relates both to the people alive today and to future generations, and proposes that every person should be capable of

1. being able to live to the end of a normal human lifespan and not having to die prematurely;
2. being able to have adequate nourishment, shelter and good health, and being able freely to express their sexuality;
3. being able to live without unnecessary pain and suffering;
4. being able freely to exercise imagination, thought and logic and to practise a religion;
5. being able to maintain attachments to things and people and to experience and cherish interpersonal values like love, care, gratitude but also longing and grief;
6. being able to form their own conception of a good life and plan their own life;
7. being able to engage in social interaction and to experience recognition, community, friendship and professional life;
8. being able to live well in relation to animals, plants and the world of nature;
9. to be able to laugh, engage in recreation and experience enjoyment;
10. being able to participate politically, freely carry on an occupation under fair working conditions, and acquire property.

This list includes aspects which go far beyond the definition of an absolute material living standard. In fact, it comprises all those capabilities which universally characterize quality of life and human dignity. Naturally, the capabilities approach is first and foremost a theory-of-justice model that was developed by philosophers. Ultimately it is the responsibility of countries to ensure that their citizens can develop and exercise all of the capabilities. Looking at the living conditions in developing countries, however, fulfilment of this standard for all people still seems a very remote prospect. This is not a complaint against the capa-



1.8 > A hillside vineyard in Radebeul near Dresden. Economists assign vineyards to the category of cultivated natural capital.

bilities approach, though, but much more against the political and economic circumstances. One strength of the approach is that it contains a list of aspects which are transferable to all cultures. Over time, the capabilities approach has been taken into account in many UN documents. It has thus established itself as an important basis for the political discourse about the responsibility of those alive today towards the people of the future.

If we follow the capabilities approach, the question is which things people alive today should bequeath to future generations to ensure that the people of the future can likewise attain the 10 capabilities and live fulfilled lives. Experts talk about this in terms of a "fair bequest package". For a good education, people need libraries, for the transportation of goods they need roads, for food production they need fertile farmland, for clean air they need forests. Beyond this, the fair bequest package also includes natural landscapes, which are all the more important because people can only develop the capability to enjoy nature by experiencing these landscapes themselves. This capability is in no way a luxury for human life but is accepted as one of the basic ideas of a good life.

Capabilities like the capacity to enjoy nature may appear abstract. But they are all linked to a concrete resource. The capability to engage in recreation, for example, presupposes that there are forests to walk through, beaches for bathing, and urban green spaces where people can relax. Economists refer to such resources as different types of "capital":

1. real capital (machines, factories, infrastructure);
2. natural capital (forests, oceans, rivers, coasts);
3. cultivated natural capital (commercial forests, livestock herds, vineyards, agricultural land, aquacultures);
4. social capital (political institutions, social cohesion, sources of social solidarity);
5. human capital (skills, education);
6. knowledge capital (libraries, universities).

In the sustainability debate, the natural forms of capital are of greatest importance. These are characterized specifically as follows:

- renewable or self-regenerating resources (for example, plants and animals) and non-renewable resources (for example, metal ores, petroleum);
- original natural capital (unregulated rivers, primary forests) and cultivated natural capital reshaped by human activity;
- sources (for example, minerals from the mountains), sinks (for example, the ocean as a carbon dioxide reservoir) and stocks (for example, animal populations).

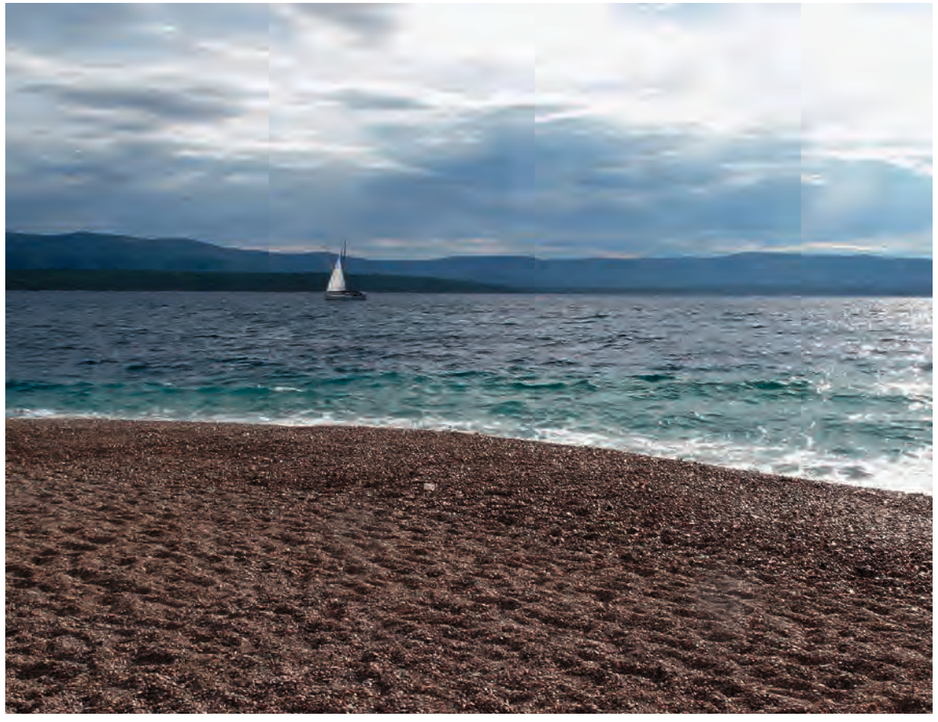
Today sustainability theorists increasingly emphasize that the various forms of natural capital encompass not only material but non-material values, such as the recreational effect of beaches and forests. The theorists talk about the welfare effect of natural capital and emphasize that the degradation of natural capital goes hand in hand with the loss of such values.

Weak versus strong sustainability

To what extent certain forms of capital, particularly natural capital, should be conserved for posterity has long been a contentiously debated issue. Since the 1970s, the debate has circled around the following two contrasting models: the model of weak sustainability and the model of strong sustainability.

According to the weak sustainability model, only the sum total of a society's capital stocks needs to be held constant. By that standard, it is possible for capital resources that have been consumed to be replaced with different types. In principle, then, there is unlimited scope for substituting natural capital with real and human capital. Under the weak sustainability model, these substitution processes are permissible almost without restriction. Even destroyed elements of natural capital, such as rivers that are biologically dead due to pollution, can be replaced under this model. The recreational function of river bathing, for example, can be substituted by constructing open-air or indoor swimming pools; obtaining drinking water not purely from groundwater but alternatively from desalinated seawater; or replacing the aesthetic quality of natural landscapes with artificial, virtual worlds. According to the model of weak sustainability, all that matters is to satisfy the sum total of people's needs – irrespective of which type of capital is utilized.

Particularly in the 1970s, a period of great environmental degradation, many economists believed in the idea of weak sustainability. Some of its proponents note that



1.9 > The Golden Horn, one of Croatia's most popular beaches. Not just the Adriatic but every sea in the world has so many different functions that it can never be substituted in full. The recreational function is one of these.

critical natural capital stocks – i.e. stocks that are very difficult to substitute – are indeed worth conserving. When a form of natural capital should be classified as critical is often a matter of dispute, however.

Strong sustainability for environmental quality

While some economists still stick with the model of weak sustainability, scholars in other scientific disciplines consider it a write-off: today it is generally accepted that not every form of natural capital is indiscriminately substitutable. If we consider the scale and the consequences of the destruction of natural capital today, the limits of substitutability become very much clearer than in economic models. This is particularly true of multifunctional natural capital, i.e. forms of capital which fulfil several functions simultaneously. Oceans, for example, supply food, are an income source for fishers or aquaculturists and a recreational zone for millions of tourists. Completely replacing the multifunctional habitat of the ocean is impossible – hence, the idea of substitutability is obsolete. A similar argument is valid for forests with their many functions.

Over the last few years, therefore, the "strong sustainability" model has gradually gained ground in sustainability theory, and is becoming increasingly widespread in the political sphere. The aim of strong sustainability is to conserve natural capital, regardless of whether and to what extent it is substitutable or how other capital stocks such as real capital (for example, in the form of industrial and consumer goods) might develop. In keeping with strong sustainability, natural capital has to be conserved because of its many different functions – not only because of its material values, but also its cultural values, for example.

So the question is not just whether natural capital can be substituted but, more importantly, whether humankind actually desires a permanent substitution now and in future. The generation living today cannot judge what needs and cultural value ideals future generations will have, and whether those yet to be born are in agreement with the substitutions we make today. Substitution of natural capital, in other words ultimately the loss of natural habitats and the decline of biodiversity, is irreversible and scarcely justifiable. If natural capital is consumed today, it no longer remains available as an option to the people as yet unborn. In that case, generations to come no longer have the choice between natural capital and the substitute, but have to live with the substitute.

Since the strong sustainability model decrees that present-day amounts of natural capital should be held constant, it means that the destruction of natural habitats and degradation of environmental systems must be halted.

Modern sustainability models try to reconcile the economic use of natural capital with its conservation. To make this possible, however, a few rules are necessary. One example is known as the Constant Natural Capital Rule (CNCR) which requires maintaining the sum total of natural capital. This in no way implies a kind of museum-style nature conservation which totally prohibits any modification of near-natural areas. In fact, the CNCR's aim is the conscious use of natural capital and, above all, the substitution of consumed natural capital with other natural capital of equivalent value.

It is important to emphasize that according to the CNCR there is not just one way to replace natural capital. Strong sustainability does not force any ideal path upon policymakers from which they must never stray. Rather, the CNCR requires people to be creative in seeking good solutions for any substitution of natural capital. Thus, a harvested tree might be replaced with a tree of a different species. It is even conceivable that a certain forest biotope might be substituted with another. In some cases, near-naturally managed forests could fulfil the functions of destroyed virgin forests. It may also make sense to build up natural capital in the form of plantations if virgin forests elsewhere might be protected as a result.

The CNCR represents a modern, flexible and practicable rule of strong sustainability which can be used to resolve conflicts over use. The major difference from weak sustainability is that according to the CNCR, consumed natural capital must be replaced by equivalent natural capital. The CNCR approach does not allow substitution with real capital, nor exclusively technical solutions, as in the substitution of clean river water by water from seawater desalination plants.

The multilevel model – a bridge between academic theory and operational practice

In recent decades, German scientists have sought to establish a comprehensive perspective on "sustainability". Basic theories rooted in philosophy and ethics were linked with economic theories and knowledge from the natural sciences.

A notable example is the multilevel model developed in the 1990s. It was devised by its authors as a multi-stage process consisting of discrete mental building blocks, referred to as levels. Its aim is to derive concrete actions and measures from sustainability theory and to create a bridge between sustainability theory and real environmental policy.

- On the uppermost level, the ethical principles of the sustainability idea are reflected. Here it is also clarified how far people bear a responsibility towards subsequent generations and how through their behaviour, they influence the life-support base of their descendants. This discourse concludes with the demand that people living today are obliged to preserve a legacy which enables future generations to meet their own needs.

- On the second, strategic level there is discussion of what makes up such a legacy, i.e. which assets, resources and forms of capital should be preserved on what scale. At this point the authors speak out in favour of a strong sustainability model because natural capital cannot be substituted indiscriminately.

- On the third level, a framework of rules for sustainability is drafted. Top of the agenda here is the Constant Natural Capital Rule (CNCR), which imposes the obligation to conserve natural capital over time. Essentially only as much natural capital should be consumed as nature can replenish. Examples are the use of renewable energies instead of fossil fuels or the prudent management of fish stocks. For regions which were subject to large-scale destruction and consumption of natural capital in the past, an investment rule applies, its purpose being to correct as far as possible the overexploitation and mistakes of the past. The recultivation and restoration of previously degraded natural areas belong under this heading. Other management rules specify exactly whether and how much natural capital may still be used in future.

- The fourth level defines three normative guidelines for sustainable action. These guidelines are efficiency, sufficiency and resilience. Efficiency relates to the economy. It requires modern, more efficient technologies to be developed; for example, engines with higher energy-conversion efficiency. Sufficiency is addressed to a sustainable lifestyle. On the one hand it demands that all people worldwide should be enabled to meet their basic human needs. It sets the industrialized countries the target of striving for a lifestyle with the least possible consumption of raw materials and energy. According to this guideline, the industrialized countries are called upon to develop post-materialistic prosperity models. This is not in any way about forcing people into an ascetic way of life. Rather, it revolves around the rejection of individual utility maximization, or creating islands of deceleration and blurring the rigid boundaries between work and leisure. Resilience relates to the conservation of natural capital itself, but also to maintaining the various functions that such capital has, such as recreation. Generally resilience refers to the capacity of a habitat to withstand disturbances. Previously damaged habitats are often less resilient. One aim is therefore to protect habitats accordingly.

- On the fifth level policy-making and action areas are defined in which sustainability is to be achieved. These include areas like nature conservation, agriculture and forestry, fisheries and climate change. Such a breakdown into different areas is important in order to be able to plan and implement measures as specifically as possible.

- On the sixth level, goals are derived in the most concrete possible terms. For example, it has been resolved to reduce the discharge of nutrients into the Baltic Sea by 50 per cent in the next few years. But it is not always possible to specify a precise target value, as it can be unclear at what value sustainability is reached. For example it is not necessarily possible to determine how high the share of dead wood should be in a sustainably managed, near-natural forest. In such cases, a kind of target zone, a broader corridor of targets, can be defined. As a matter of principle, diverse stakeholder groups should be involved in setting target values.

- On the final level, instruments are developed to support the achievement of concrete sustainability goals, along with monitoring systems to help verify whether these have actually been attained.

The value of nature

> If people intend to make prudent and sustainable use of natural resources, they must determine in what manner and to what extent they wish to utilize the natural world or conserve it. This is only possible if they can make an accurate assessment of the costs and benefits. It can be helpful in this context to look at nature in economic terms as natural capital. Nevertheless, it is highly problematic to put a value on the services of nature.

Nature – a gigantic service provider

For time immemorial nature has been providing human beings with the resources they need for survival; things like fruits, grains, fish, meat or wood. It also puts a free supply of clean air and clean water at our disposal. Economists group all these aspects together under the heading of natural capital. In simplified terms, natural capital is defined as the stock of natural assets such as the soil, forest or ocean, which generate natural products and services such as fresh air or potable water.

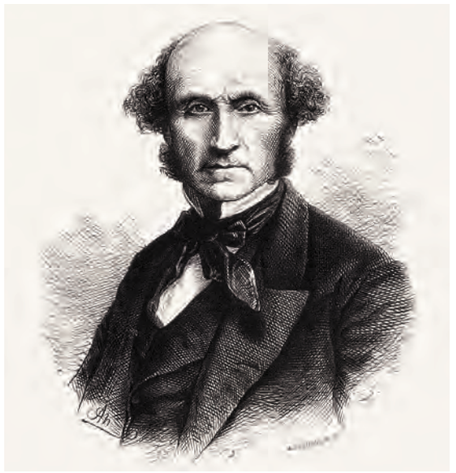
Measured against the several-centuries-old history of economics, the concept of natural capital is still very new. It was only coined in the second half of the 19th century. Until then, economists took nature and its services for granted. The sole exception was fertile agricultural soil. Before the invention of artificial fertilizers, the fertility of soils and hence their yield was limited. The productivity of farmland could not be increased at will because the quantity of nutrients was limited. Since adequate food had to be produced for the population nevertheless, large areas of land had to be farmed, and the number of people working in agriculture was very high.

After the German chemist Justus Liebig had invented artificial fertilizer in the mid-19th century, the situation changed. The productivity of farmland was increased several times over. Fewer farmers could harvest more crops. This released workers who were needed in the factories of the growing industrial towns. The importance of soil as an economic factor diminished. Instead, many economists came to consider real capital, in the form of machinery and infrastructure, as the only factor determining economic growth.

1.10 > One of the first blast furnaces, in Coalbrookdale, England, in the year 1801. During the Industrial Revolution a paradigm shift took place in economics. Many experts lost sight of the significance of soil and the services of nature as economic factors. Only the investment of real capital was thought to determine economic growth.

Never-ending harvest?

Very few thinkers gave more sophisticated consideration to nature and its services. Among them was the English philosopher and economist John Stuart Mill, who emphasized in the 1870s that nature ought also to be preserved for the sake of its intrinsic charm. Mill wanted to halt population growth. He feared that humankind would continue to destroy near-natural, aesthetic landscapes if the human population continued to expand.



1.11 > The English philosopher and economist John Stuart Mill noted in the 1870s that nature would suffer further destruction unless population growth was halted.

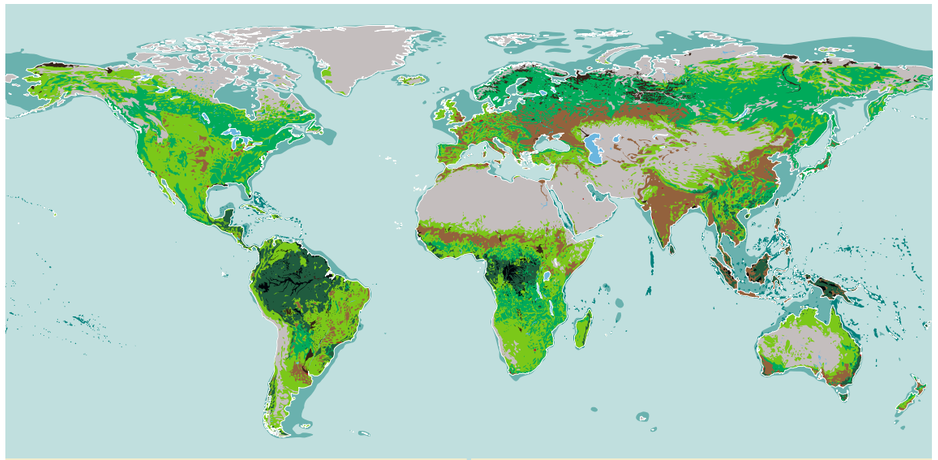
At this time more concrete work was being done by the French economist Léon Walras, who published his *Elements of Pure Economics, or the Theory of Social Wealth* in 1874. Among other issues, he deals at length with the services of nature in his work, and develops the concept of natural capital. Walras, too, initially considers nature as an inexhaustible source because in his view natural capital cannot be destroyed entirely. On the contrary, he says, year after year it keeps supplying new products. Walras refers to this fertility of nature as a service, and to the yields that agriculture produces as "rents". However, Walras recognizes that natural capital, like other forms of capital, can become scarce and that its value rises as a result: "the quantity of land can be very limited in an advanced society, relatively to the number of persons […] and has a high degree of scarcity and value". Walras makes further distinctions and writes that natural capital can be used in two ways: firstly, as existing capital stock from which long-term income is generated – for example, an apple tree that provides fruit for many years – and secondly, as capital that is used directly – for example if someone cuts down the tree and sells the wood. Walras's approach was extraordinarily modern in its analytical breakdown of the concept of natural capital. Even today, experts still make a similar distinction between stock and flow variables – in other words, between natural capital that is used and consumed directly, and natural capital that provides a continuous flow of rents over a longer period of time.

Despite Walras's publications, natural capital played no part in economic theory for around another 100 years because economists were convinced that there could be no absolute scarcity of natural capital.

Is the value of nature measurable?

Today the concept of natural capital is well established. Even so, how the value of nature should actually be estimated is still a contentious issue. This question is important when it comes to quantifying the losses caused by progressive degradation of nature or assessing whether it is economically viable to invest in natural capital. Investment projects of this kind may include the restoration of degraded natural landscapes to a more natural state, or the near-natural management of forests. The valuation or monetization of natural capital is a huge challenge, particularly because natural capital does not take just one but many different forms – forests, rivers, meadows or the ocean. And all of them provide different services.

1.12 > World map with the different ecosystem types and the calculated values of their ecosystem services (in US dollars per hectare per year).



Ecosystem types	A	B
Desert, tundra, ice and rock	4232	0
Open ocean	33200	491
Coastal and shelf areas	2660	2222
Grass and pastureland	4418	2871
Forests in temperate and northern latitudes	3003	3013
Rivers and seas	200	4267
Rainforest	1258	5264
Arable land	1672	5567
Conurbations	352	6661
Floodplains and swamplands	60	25682
Salt marshes and mangroves	128	193845
Coral reefs	28	352249

A: Size of area in millions of hectares, B: Monetary value per hectare per year in US dollars

Ecosystem service

Economists and sustainability theorists call any service that nature provides an "ecosystem service". Examples are the availability of potable water, fresh air, or food in the form of fish and fruits. Added to these are aspects which are not directly measurable like the beauty of a landscape that provides people with recreation. "Natural capital", in turn, denotes the natural resources which produce all these ecosystem services.

In 1997 a team of American scientists and economists published a study in which they attempted to document the total value of services provided by all **ecosystems** worldwide. They came to the conclusion that global natural capital including these various ecosystem services generates 33 thousand billion US dollars per year – almost twice as much as **global gross national income** which amounts to 18 thousand billion US dollars. In this study, the oceans accounted for the lion's share, valued at 21 thousand billion US dollars.

For their study the scientists had divided the globe into around 20 ecosystem types and seventeen ecosystem services, such as climate regulation, water storage or food production. Subsequently, for every ecosystem and every service they determined the value of one hectare and then calculated projections for the total global area. In 2011 a new study was presented in which the data from 1997 was re-evaluated and the ecosystem services updated. One of the most important findings of this study was that because of land-use changes, the value of ecosystem services had fallen from 1997 to 2011 by at least an average of 4.34 thousand billion US dollars per year. Land-use changes are processes like the conversion of tropical rainforests and wetland areas into productive agricultural land.

There was massive criticism of these studies. Experts complained that the projections were unreliable because they drastically oversimplified matters and did not adequately take account of the diversity of ecosystems. Another criticism was that having arrived at a figure, it was completely unclear which political consequences were to be drawn from it. Thus the studies provided no action guidelines on which natural capital ought to be protected or how. Although the first study appeared in the respected scientific journal *Nature* in 1997, today it is viewed less as a profound scientific paper and more as a politically motivated publication. As such, the experts say, it is significant because it showed for the first time what order of magnitude the value of natural capital can actually reach.

Ecosystem service*	Ecosystem functions	Examples
Gas regulation	Regulation of atmospheric chemical composition	CO_2/O_2 balance, O_3 for UVB protection, and SO_x levels
Climate regulation	Regulation of global temperature, precipitation, and other biologically mediated climatic processes at global or local levels	Greenhouse gas regulation, DMS production affecting cloud formation
Disturbance regulation	Capacitance, damping and integrity of ecosystem response to environmental fluctuations	Storm protection, flood control, drought recovery and other aspects of habitat response to environmental variability mainly controlled by vegetation structure
Water regulation	Regulation of hydrological flows	Provisioning of water for agricultural (such as irrigation) or industrial (such as milling) processes or transportation
Water supply	Storage and retention of water	Provisioning of water by watersheds, reservoirs and aquifers
Erosion control and sediment retention	Retention of soil within an ecosystem	Prevention of loss of soil by wind, runoff, or other removal processes, storage of stilt in lakes and wetlands
Soil formation	Soil formation processes	Weathering of rock and the accumulation of organic material
Nutrient cycling	Storage, internal cycling, processing and acquisition of nutrients	Nitrogen fixation, N, P and other elemental or nutrient cycles
Waste treatment	Recovery of mobile nutrients and removal or breakdown of excess or xenic nutrients and compounds	Waste treatment, pollution control, detoxification
Pollination	Movement of floral gametes	Provisioning of pollinators for the reproduction of plant populations.
Biological control	Trophic-dynamic regulations of populations	Keystone predator control of prey species, reduction of herbivory by top predators
Refugia	Habitat for resident and transient populations	Nurseries, habitat for migratory species, regional habitats for locally harvested species, or overwintering grounds
Food production	That portion of gross primary production extractable as food	Production of fish, game, crops, nuts, fruits by hunting, gathering, subsistence farming or fishing
Raw materials	That portion of gross primary production extractable as raw materials	The production of lumber, fuel or fodder
Genetic resources	Sources of unique biological materials and products	Medicine, products for materials science, genes for resistance to plant pathogens and crop pests, ornamental species (pets and horticultural varieties of plants)
Recreation	Providing opportunities for recreational activities	Eco-tourism, sport fishing, and other outdoor recreational activities
Cultural	Providing opportunities for non-commercial uses	Aesthetic, artistic, educational, spiritual, and/or scientific values of ecosystems

* We include ecosystem "goods" along with ecosystem services.

1.13 > In order to assess the total value of services provided by all ecosystems worldwide, in 1997 US researchers defined various ecosystem service categories. Although the study was criticized because it massively simplified the worldwide situation, it was nevertheless a milestone because it made clear the vast overall economic significance of ecosystem services in their entirety.

Different types of services

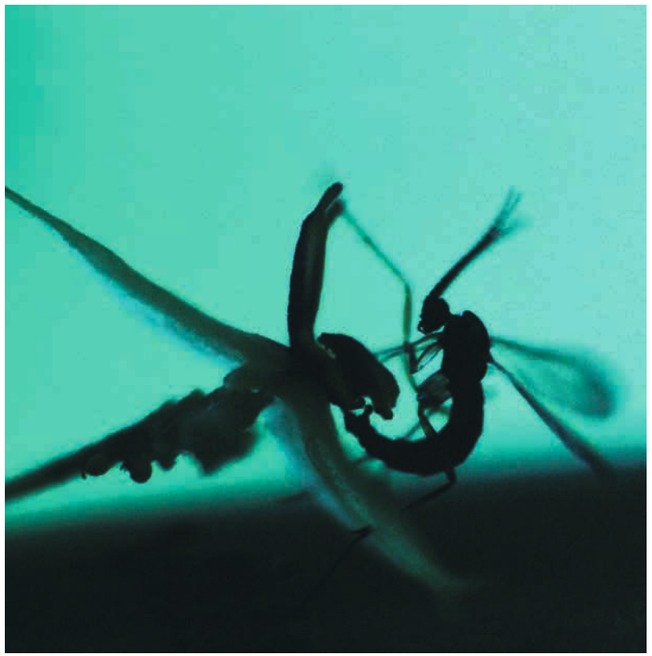
The publication of the study in 1997 prompted the question of whether it was even permissible to give natural capital a monetary value. One of the arguments voiced was that natural capital is vital to human survival, irreplaceable, and hence of infinite value; monetization was inappropriate. Very few experts still defend this extreme position today. Nowadays only "primary values" which represent the basis for life on Earth – such as solar radiation, fresh water or atmospheric oxygen – are considered to be non-monetizable. Putting a price on such primary values would make little sense.

What is certain is that a monetary value can only be applied to natural capital if it is considered on a smaller scale. Thus it is virtually impossible to determine the value of the sea in its totality, but very much easier for a particular marine region or a specific service. Before one can even attempt to value natural capital, it must first be categorized. The United Nations (UN) launched an attempt to do so in 2001 with the major international project, the Millennium Ecosystem Assessment (MEA), in which several hundred researchers analysed all ecosystems worldwide and allocated them to different categories of services:

- Supporting services, which maintain the ecosystem itself, such as nutrient cycles or genetic diversity;
- Provisioning services, which produce food, water, building material (wood), fibres or pharmaceutical raw materials;
- Regulating services, which regulate the climate, ensure the absorption of wastes and air pollutants, or are responsible for good water quality or for plant pollination;
- Cultural services, which facilitate recreation, nature tourism, aesthetic pleasure and spiritual fulfilment.

Although such a breakdown can be helpful for the monetization of natural capital, many ecosystems and the multitude of interrelationships among living organisms are so complex that their significance and performance, and hence their value, cannot be captured in their entirety. It is hard for scientists even to assess what consequences might result from the disappearance of a single animal species, such as a predatory fish species, let alone the destruction of an entire ecosystem. Orchids in the rainforest, for example, are found to be pollinated by one sole insect species in some cases. If the insect is lost, the orchid dies out, and this in turn affects other animal species which are dependent on it. If this relationship goes unrecognized, the value of the insect species will be underestimated.

The valuation of ecosystems is also complicated by the diverse ways in which they are interwoven and reciprocally influence each other. Researchers are often virtually unable to discern these dependencies – and hence also the services that ecosystems provide for one another. A mountain forest, for instance, stabilizes the soil. If the mountain forest dies, erosion escalates. Soil is washed into streams and rivers, which also affects the living conditions for marine organisms in coastal waters.



1.14 > Part of the flower of the orchid species *Lepanthes glicensteinii* is shaped like the genitalia of a female fungus gnat. Deceived into copulating with the flower, the male picks up pollen, with which it subsequently pollinates other plants – an example of a regulating ecosystem service.

The value of nature – today and tomorrow

Thus, in order to be able to assess the value of natural capital in a manner that captures the linkages and dependencies, even finer differentiations must be made. Economists attempt to do so by assigning the ecosystem services of nature to different value categories. The total value of any given natural capital is then obtained from the sum of all its services – experts talk about the Total Economic Value (TEV) of an ecosystem. Under the TEV approach, an initial distinction is made between the use value resulting from the use of the natural capital, and the non-use value which the natural capital represents in itself. The use value and non-use value are then broken down still further.

The use value includes:

- the direct use value, provided for example by a fish that has been caught. This value can be expressed in concrete terms for any given service in the form of a market price;
- the indirect use value, such as the climate-regulating effect of a forest, or the sea, or natural water purification in the soil;
- the option value which arises through any potential future use of the given natural capital; for example, pharmaceutical ingredients which are obtained from marine organisms.

The non-use value includes:

- the existence value that human beings attach to creatures like blue whales or to habitats like mangrove forests, without necessarily thinking that they will be able to use or even experience these habitats themselves in future. The existence value arises from the sheer delight of knowing that these creatures or habitats exist;
- the bequest value, which exists because people feel the desire to pass on natural resources as intactly as possible to subsequent generations.

The MEA and TEV are related approaches. Thanks to the two, the significance of ecosystems can better be assessed today, although both only classify rather than supplying any concrete monetary values. While the objective of the MEA was to gain an overview of global ecosystems and ecosystem services, TEV makes much finer distinctions in respect of these services. TEV results in a better assessment not because it combines all values into a composite value, but rather because it takes account of different value categories in the first place. This makes it possible to compare the significance of different ecosystem services with one another.

Today it is known that many ecosystems, and hence also forms of natural capital, are in poor condition. As an approach to improving the situation, however, it makes little sense to establish some total value of natural capital in monetary terms. The pertinent question is rather, which measures might be used to prevent the destruction of an ecosystem, or how its condition might be improved. Normally a host of concrete measures are available for this purpose, which must be weighed against each other. As part of this, prior categorization of the ecosystem services using TEV is helpful.

For example, for several years now the British Department for Environment, Food and Rural Affairs (Defra) has been using TEV for the valuation of nature conservation measures such as the restoration of bird sanctuaries. Furthermore it makes use of TEV in order to study what difference parks and green spaces make to the general health of the population by providing space for recreation, sport and outdoor exercise.

Clearly the management or conservation of parks and green spaces costs money. Moreover, it means that this land is unavailable to be built upon. But the Defra studies conclude that the gain for the population is substantial because outdoor exercise prevents illnesses. They find that a single park in an urban area saves the health system annual costs amounting to 910 000 pound sterling (around 1 150 000 euros) on condition that 20 per cent of the town's citizens make use of the green spaces. Thinking this through, it becomes clear that the total value of natural capital at the present moment is not as relevant to its

valuation as the value resulting from changes. The smaller the available park area, for example, the greater its relative value becomes because fewer and fewer square metres are available for the benefit of those seeking recreation. What is important in this context is the size of the park area to begin with. Thus, the loss of value is much greater if a few square metres are deducted from a small area of parkland than from a huge park. Equally, a few extra square metres creates much less additional value for a large park than for a small one. Changes in the value of natural capital of this kind, resulting from measures such as the destruction or creation of a park landscape, play a major part in the sustainability debate. Economists refer to this issue in terms of "marginal changes" or "marginal values".

In many cases a monetary value can be assigned to a certain category of an ecosystem service. A park that serves residents as a leisure facility, for example, has a very particular monetary value in the form of cost savings in the health system – i.e. a direct use value. It is considerably more difficult to determine the indirect use value of this park; its contribution to a better inner-city microclimate, for instance.

1.15 > The Hong Kong Park, opened in 1991, has direct benefits for citizens in the form of recreation, but also a high indirect use value because it improves the inner-city microclimate.

As a means of establishing the indirect use value of natural capital, an estimate can be made based on consumer surveys of how much a household would be willing to pay to improve environmental conditions – in this case, for example, for the enlargement of an inner-city park. Economists refer to this as "willingness to pay" (WTP). Another figure to be determined is the extent to which the population would accept compensation for any deterioration in environmental conditions (for example, if the park were reduced in size or built upon) – how great the "willingness to accept" (WTA) is.

WTP and WTA are often dependent on a cultural or societal context and are therefore impossible to determine in some cases. If a population attaches a cultural or even religious significance to a park, a landscape or a natural monument, it will be very reluctant to accept any changes to it, let alone its destruction. Many sustainability experts call for such factors to be taken into account in the valuation of natural capital, even if they are barely quantifiable.

Dearth of knowledge

How difficult it is to assess the value of natural capital is also demonstrated by a recent study conducted by German economists. The researchers analysed a range of publications on the theme of ocean acidification. They wanted to find out whether robust findings existed on the future costs of ocean acidification, and who might be affected by it.

Ocean acidification is, alongside global warming, one of the most feared consequences of climate change. The oceans absorb from the atmosphere a large proportion of the greenhouse gas carbon dioxide that is emitted by the burning of natural gas, petroleum and coal. Expressed in simple terms, this results in a build-up of carbonic acid in the water, and the pH value of the water gradually drops. Marine scientists fear that this could affect corals and fish larvae as well as bivalves and snails which produce calcareous shells.

The study found that publications on the economic impacts of ocean acidification largely deal with the direct

1.16 > The indigenous inhabitants of Australia, the Aborigines, believe that their continent is crisscrossed with invisible, mythical dreaming tracks – a special kind of cultural natural capital that was often fragmented or destroyed by construction schemes.

1.17 > In September 2009 fishers and other seafarers along the Pacific coast off Alaska protested against ocean acidification.

pH value
Chemists determine the acidity of a liquid with reference to the pH value. The lower the value, the more acidic the liquid. pH values range from 0 (very acidic) to 14 (very alkaline). Since the Industrial Revolution the pH value of the oceans has fallen from an average of 8.2 to 8.1. By the year 2100 the pH value could decrease by a further 0.3 to 0.4 units. That sounds negligibly small. But the scale of pH values is logarithmic. It is mathematically compressed, so to speak. In reality the ocean would then be 100 to 150 per cent more acidic than in the middle of the nineteenth century.

economic impacts on human beings, and particularly with the consequences for the fishing industry. Just a few papers analyse the situation with regard to coral reefs. While these mention that coral death could cause losses in tourism revenue, they stop short of any precise economic analysis. Moreover, not one publication mentions the indirect consequences of coral death; for instance, it would also have a detrimental effect on coastal protection. The authors of the study list a number of gaps in existing research content:

- A majority of the economic studies focus on direct economic impacts such as a decline in the catch of fish or shellfish in certain marine regions. Existence or bequest values are left out of the analysis.
- No knowledge is available as yet on how the pH value in coastal waters might change in the future. Hence it remains unclear which marine regions are likely to be most heavily affected. But precisely that knowledge is important in order to ascertain the magnitude of the economic consequences in situ – and to intervene with well-targeted counter-measures.

Another fundamental problem is that the findings on ocean acidification in scientific publications are often presented in a form that is not usable for an economic analysis. Often, simplifying assumptions are necessary in order to be able to project changes in the gross revenues of fishers from data on changes in a calcification rate in bivalves.

Accordingly, the authors come to the conclusion that it is simply not possible to assess the economic impacts of ocean acidification today because even just the marine biochemical processes are too complex. Furthermore, many published studies refer to organisms which are easy to observe or to keep in a laboratory but which have absolutely no claim to any particular economic relevance or vital importance to ocean food webs. Since the scientific journals are the basis for the economic studies, their credibility in turn must be considered very limited.

The authors of the study therefore propose closer cooperation between natural scientists and economists for the future, addressing not just ocean acidification but all other environmental threats and ecosystem services as well. In collaboration it would be possible to tackle natural sciences research topics which are also of economic significance. Perhaps in that context organisms might be selected for studies specifically because they are interesting from a market economic viewpoint.

Prioritized for protection: critical natural capital

The forms of natural capital of particular interest today are those which are so significant that everything possible should be done to prevent their destruction. Sustainability theorists refer to these as critical natural capital stocks. A majority of experts include in this category forms of natural capital which are not substitutable by anything else – for example, scarce groundwater resources in the arid zones of Africa. This critical natural capital must be preserved because it is of elementary importance for human beings.

Other experts say critical natural capital also includes natural areas which merit protection not because they are existentially important to people but because they are habitats for threatened plant and animal species. This somewhat broader view of critical natural capital is supported by nature conservationists in particular – among them, the British environment agency “Natural England” (“English Nature” until 2006). Back in the 1990s this agency defined several categories which can help to identify land-based critical natural capital:

- Small-scale habitats with rare or threatened organisms;
- Ecosystems that represent a characteristic habitat with all the typical plant and animal species;
- Areas that provide important services such as protection against erosion, absorption of environmental pollutants or provision of drinking water;
- Areas of geological significance, particularly geological formations like the Grand Canyon in the USA, which are of special scientific interest or unique character.

Sustainability theorists stress that critical natural capital is definitely not to be equated with pristine wilderness, for often it is actually natural capital cultivated by people and already in use. Hence, continued prudent use is already well established, they argue. Nevertheless, in many cases they would insist on the need to define precise threshold or limit values which must not be exceeded, as otherwise unacceptable losses of natural capital will occur.

Uniting to conserve natural capital

The good news is that over the years a number of large-scale initiatives have been successful in protecting different forms of critical natural capital. Noteworthy successes have been the establishment of national parks and the adoption of various international conventions or special directives on nature conservation. In these cases the urgency of the need for action was plain to see, making it unnecessary to determine the value of the natural capital in detail beforehand.

One example of these forward-thinking conservation efforts was the International Montréal Protocol of 1989, which prohibited the use of chemical substances that deplete the ozone layer. To this end, very concrete limit values for the production of chemicals were specified. The signatory countries made a commitment to reduce and ultimately completely phase out the emission of particular substances. In this way it was possible to conserve the ozone layer as a primary value and as natural capital of life-and-death importance.

A further example is the Washington Convention (Convention on International Trade in Endangered Species of Wild Fauna and Flora, CITES) which has strictly regulated trade in rare or endangered species since 1973.

Millennium Development Goals

In September 2000, heads of state and government from 189 countries gathered in New York for, at that time, the largest ever summit of the United Nations. They adopted the Millennium Declaration which sets out a four-point list of the most important political challenges for the twenty-first century:

- Peace, security and disarmament,
- Development and poverty eradication,
- Protection of the common environment,
- Human rights, democracy and good governance.

Taking these major challenges as a basis, a working group made up of representatives of the United Nations, the World Bank, the International Monetary Fund and the Organisation for Economic Co-operation and Development (OECD) derived the following eight Millennium Development Goals (MDGs):

- MDG 1: To eradicate extreme poverty and hunger;
- MDG 2: To achieve universal primary education;
- MDG 3: To promote gender equality and empower women;
- MDG 4: To reduce child mortality;
- MDG 5: To improve maternal health;
- MDG 6: To combat HIV/AIDS, malaria and other diseases;
- MDG 7: To ensure environmental sustainability (integrating sustainable development into country policies, protecting environmental resources, reducing biodiversity loss, enabling people to access safe drinking water);
- MDG 8: To develop a global partnership for development.

For each goal, specific subsidiary targets were defined and time-frames specified for achieving them. Some of these efforts were a resounding success; for instance, the target of halving, from 1990 to 2015, the number of people worldwide whose income is less than 1,25 US dollar per day. This target was actually achieved in 2010.

Other targets, however, proved impossible to implement. The reasons for this failure were many and varied. Some were simply too ambitious. In other cases, the practicalities of implementation on the ground rendered the goals and targets unattainable. The process itself was not without problems: critics have pointed out that development funding which the Group of Eight (G8) major industrialized nations had contributed to funds managed by the World Bank, the International Monetary Fund and the African Development Bank were often allocated to purposes for which it was not intended, despite originally being earmarked for activities in pursuit of the MDGs.

Common goals for a sustainable future

In the year 2000 a working group convened by the United Nations formulated eight Millennium Development Goals (MDGs) which were to be accomplished by the year 2015. These were intended to bring about clear improvements in the living situation of people in developing countries and emerging economies and, at the same time, to conserve various forms of natural capital. The MDGs undeniably focus on the reduction of poverty and poverty-related hardships, and on aspects like health and education.

Today it is evident that these goals have not yet been achieved worldwide. A further United Nations working group has therefore now defined Sustainable Development Goals (SDGs) for the period from 2015 to 2030 that frame objectives in more concrete terms than the MDGs did. The SDGs are no longer restricted to the developing countries but address the whole world. Moreover, by taking the domains of sustainable agriculture, energy and climate change and the oceans into account, they are designed to have a stronger focus on the conservation of natural capital. The following aspects are considered essential to the SDGs:

- Food security and sustainable agriculture,
- Water supply and improved hygiene,
- Energy,
- Education,
- Poverty reduction,
- Resources to conduct the SDG process,
- Health,
- Climate change,
- Environment and natural resource management,
- Employment.

These aspects are sorted by priority. Taken together, they illustrate clearly that the United Nations working group has endeavoured to give balanced consideration to all the aspects that make up the classic three-pillar model of sustainability. Developments over the coming years will show whether states actually succeed in striking this balance.

Conclusion

"Sustainability" – a difficult concept to define

For all its positive connotations, these days the concept of "sustainability" is so broadly conceived as to make it ill-defined and vacuous. Originally, "sustainability" meant something like: making only such use of natural, renewable resources that people can continue to rely on their yields in the long term. The concept was coined by Hans Carl von Carlowitz, chief mining official of the Principality of Saxony. Faced with massive deforestation caused by the demand for fuelwood for metal smelting, in 1713 he called for "continuously enduring and sustainable use" of the forest. But the concept only became a buzzword in the 1980s with the publication of the report by the World Commission on Environment and Development (WCED). In response to rising environmental degradation since the mid-1950s, the WCED defined several major sustainability goals which included reducing poverty, stimulating economic growth in developing countries and protecting the environment. However, the report lacked a clear model of how to achieve sustainability. To be sure, the "three pillars" model which envisions sustainability resting on the supports of the environment, economy and society was derived from the WCED report, but it also became apparent that these aspects are not treated as equal in status. Until now, economic interests have tended to be a higher priority than environmental protection.

An important precondition for sustainable development is that what is actually deemed worthy of protection must be clearly defined. In this context experts make use of the concept of natural capital. This comprises all stocks of natural assets, for example the soil or the ocean, which give rise to natural products and services such as fresh air or drinking water. How strictly these natural assets are to be protected is a matter on which there are still divergences of opinion. For instance, experts differentiate between strong and weak sustainability. According to the model of weak sustainability, forms of natural capital that have been consumed can in principle be replaced without limit by real capital and human capital. According to the idea of strong sustainability, in turn, forms of natural capital can only be consumed if they can be replaced by equivalent natural capital.

To determine the significance of different forms of natural capital more precisely, experts analyse which different types of ecosystem services they provide. These include aspects like the climate-regulating effect of the ocean, for example, as well as aspects that are not directly measurable like the beauty of a landscape. In many places natural capital is under threat or has already been destroyed by environmental degradation. However, the prevention of further damage or the restoration of previously damaged areas costs money. For that reason, various conservation measures are often weighed against each other in cost-benefit analyses. But while the costs can mostly be established easily, the benefits of many ecosystem services are quite difficult to quantify. In order to have some means of assessing the economic value of an ecosystem service nevertheless, experts have defined different value categories. Some of these arise from the use of natural capital and some from its mere existence. Hence natural capital also has an existence value, which arises from the sheer pleasure of knowing that certain creatures or habitats exist.

As a basic principle, scientists advise prioritizing the protection of both critical natural capital and ecosystem services, which means all those which are existentially important for humans – such as scarce groundwater resources in arid zones.

2 How the sea serves us

> Many of the ecosystem services provided by the sea are threatened today by overexploitation, environmental pollution and greenhouse gases. Yet in many cases, how severely individual habitats are degraded and ecosystem services are impaired is just not known. Researchers are therefore attempting to assess the exact condition of marine ecosystems. Such analysis is important in order to plan concrete protection measures and to define critical limits and target values.

The bounty of the sea

> Since time immemorial we humans have been living with the seas and from their bounty. They provide us with food, mineral resources, transportation routes and other services. The climate-regulating effect of the oceans and the biochemical processes that take place in the sea are of fundamental importance. Today, some of these services are under threat, which is why it is time to develop approaches for more sustainable use of the seas.

From ocean threat to ocean under threat

For millennia the sea seemed infinitely vast. Coastal dwellers, fishers and seafarers perceived it as overpowering and even threatening although it was the basis of their livelihoods. Myths of sea monsters and sea gods grew up around its unfathomable depths.

In most countries and regions, the sea has long been demystified, and it is becoming apparent that the oceans are by no means as invulnerable as our forebears believed – on the contrary: today humans are influencing and harming the ocean. We are discharging toxic substances and excessive nutrients into the sea and plundering fish stocks. Due to emissions of the greenhouse gas carbon dioxide, large volumes of which dissolve in seawater, humans are even beginning to alter the chemistry of the water masses. Many climate researchers believe that as the atmosphere and the ocean undergo warming, ocean currents will shift in future, resulting in changing weather conditions on land. The human-induced – anthropogenic – changes taking place in the sea, the atmosphere and on land are so far-reaching that in the year 2000, scientists working with the meteorologist Paul Crutzen suggested considering the era since the beginning of the Industrial Revolution as a human-influenced geological epoch in its own right. Crutzen, one of the researchers who discovered the hole in the ozone layer, aptly names this epoch the age of humans, or the Anthropocene (from the Greek word *ánthrōpos*: human).

2.1 > A ceramic figure from the fifth century BC. Mythical figures like the Greek sea monster Scylla were popular motifs for the decoration of everyday objects.

Rising resource consumption

Although the various kinds of damage caused by humans have been known for some time, efforts to bring the global economy onto a sustainable course have had very little success, if any. Instead, the consumption of natural gas, petroleum and coal as well as metals and other resources continues to rise. Since the beginning of the 1970s, worldwide energy consumption has doubled. By the year 2035 it will increase again by more than one third, according to data from the International Energy Agency (IEA) in Paris.

In the quest for new resource supplies, humans are also encroaching ever further into the sea. Today around one third of crude oil is drilled at sea – and the trend is rising. At the same time the mineral oil industry is conquering the last bastion of the marine environment: the deep-water and ultra-deep-water zones at depths of 400 and 1500 metres respectively. Around 10 per cent of the petroleum drilled worldwide is currently recovered from such great depths. The sums invested by mineral oil corporations for offshore oil extraction are correspondingly high.

Furthermore, experts anticipate that the extraction of ores at sea could also begin in the year 2016. For instance, the Canadian mining group Nautilus Minerals definitively intends to start extracting ores off Papua New Guinea in 2016, after a dispute over financing between the corporate group and the island state was settled in the autumn of 2014. Nautilus Minerals wants to extract "massive sulphides": deposits which formed around hot volcanic vents on the sea floor and are rich in precious metals.

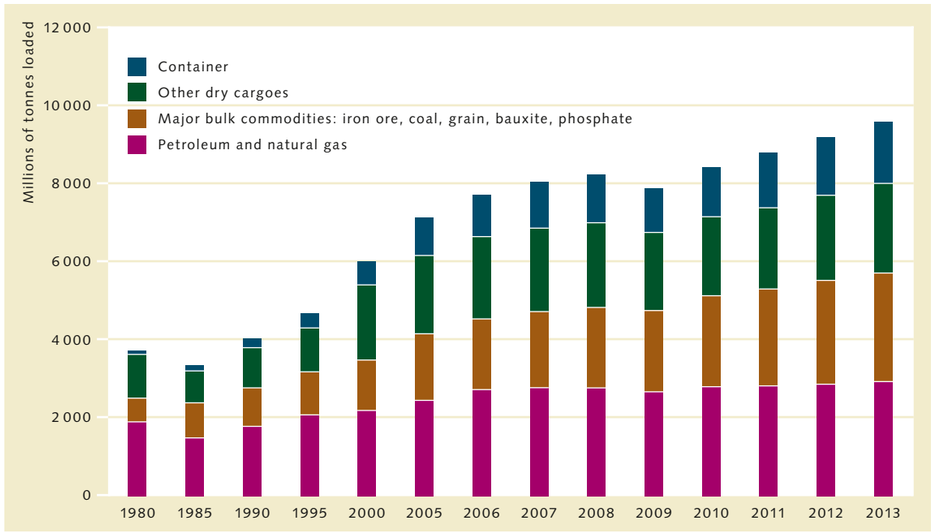
2.2 > The deep-water docks of Chinese company CIMC Raffles in Shandong Province. Up to nine drilling rigs at a time can dock at this pier, showing the vast scale on which deep-sea drilling of natural gas and petroleum now operates.

Manganese nodules or cobalt crusts, some of which are high in metal content and even contain larger quantities of certain metals overall than equivalent mineral deposits on land, are further attractions of the deep sea. The first heavy underwater vehicles are currently being built for ocean mining.

The sea – the main trading route

The sea is of great economic significance to humans in other respects as well. For instance, it is the most important trading route. Ships move more commodities than any other means of transportation. And unlike land-based roads where tolls are often payable, the trading routes across the open ocean are available for free. Ships carry petroleum, coal, ores and grain around the world. Container-loads of electrical appliances, clothing and foods are sent from Asia to North America and Europe. Crude oil from the Persian Gulf or South America is shipped in oil tankers. Apart from a decline in the cargo statistics during the economic crisis in 2008 and 2009, the quantity of goods transported by ships since the mid-1980s has constantly grown – from around 3.3 billion tonnes in 1985 to around 9.6 billion tonnes in 2013. Some 620 000 ships' officers are employed in sea travel alone. Added to these are many millions of people who work as sailors or dockers.

Above all, the sea coasts exert a special appeal to human beings. It is not by chance that many major cities, like Hong Kong, New York or Singapore, are in coastal locations. Numerous industrial plants have been and are being constructed by the sea, because raw materials and goods can be delivered and dispatched rapidly across the water. Experts estimate that today 41 per cent of the global population lives no more than 100 kilometres from the



2.3 > The oceans are the world's most important transportation routes. The volume of seaborne cargoes continues to rise since the 1980s.

sea. The United Nations believes that this figure is likely to rise further in future. In many regions, it is also boosted by the millions of domestic tourists who seek out the coasts for bathing and recreation.

The sea's most important living resource, from the human viewpoint, is fish. According to estimates by the Food and Agriculture Organization of the United Nations (FAO), today the livelihoods of 600 to 820 million people worldwide depend directly or indirectly upon fisheries. These people include fishers' families and suppliers – the makers of fishing equipment, for instance. Moreover, fish is the principal component of food in many places and a very important source of protein. Overall, about 20 per cent of humankind's nutritional needs are met from the sea. Apart from fish, crustaceans and bivalves, people also consume algae and jellyfish.

Critical issues go unseen in the sea

As pressure on the sea continues to grow, the question arises of how any sustainable use of the oceans could be achieved under these circumstances. Normally sustainability theories refer to the situation on land, where critical issues quickly become evident. If the effluent from a mine contaminates rivers and soils for a long period, for example, then there are people directly affected whose usage or property rights are infringed. Damage is normally directly visible or at least measurable. It is also obvious right away who the beneficiary is. This means that interest groups can be clearly defined, conflicts aired and negotiations conducted about a sustainable use of natural resources.

Processes in the sea remain invisible to most people, however, and are difficult to bring to light. For example, at the mouth of the Mississippi in the Gulf of Mexico, a 20 000-square-kilometre dead zone has formed in recent years which is almost devoid of oxygen. It has been caused by large quantities of nutrients discharged by agriculture into the river and then carried into the coastal region. In the sea, nutrients lead to rampant algal growth. When the algae die, they sink into the deeper water layers and are broken down by bacteria in a process which consumes oxygen. When the algae multiply especially quickly, the microbial degradation gradually exhausts all the oxygen. For higher organisms such as fish, crustaceans, bivalves and molluscs, this is disastrous: either they flee, or they die of oxygen starvation. Humans living on land barely notice any of this – with the exception of a few fishers whose fishing grounds have shrunk or shifted due to the expansion of the dead zone.

The second major difference from land is that continuous sea areas extend beyond national borders or are even – like the high seas – international areas. Ocean sustainability can therefore only be achieved if numerous nations pull together. So today it is necessary to find new approaches for sustainable ocean use which are internationally applicable above all else.

Critical limits in sight

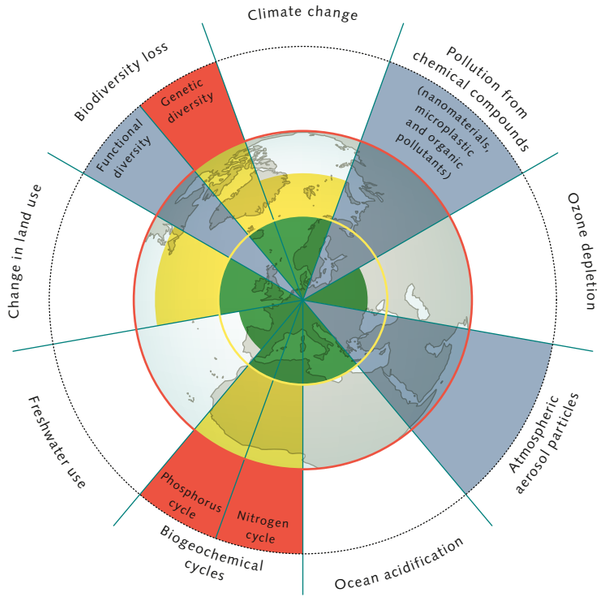
An accessible approach that is currently inspiring the international sustainability debate, and which combines the terrestrial and marine realms, is the concept of planetary boundaries. To develop this concept, which was first published in 2009 in the scientific journal *Nature* and updated in 2015 in *Science* magazine, an international Swedish-led research team asked itself how potentially catastrophic environmental changes could be avoided in future. For this purpose they defined nine essential environmental dimensions, or Earth system processes, such as climate change, freshwater consumption or ocean acidification. For seven of these dimensions – based on existing and to some extent provisional calculations – the researchers were able to quantify critical limits. If these were exceeded, they say, it could result in grave global or regional environmental changes – with unforeseeable consequences for life on Earth. In the scientists' view, this applies particularly to climate change and biodiversity loss.

In order to illustrate the potential hazards of crossing the thresholds, for every dimension three levels of risk are specified: the first is a zone of safety; the second is a zone of uncertainty or danger which indicates that the risk of grave effects is rising; and the third zone signals a high risk of grave effects or that such effects have already occurred. Large-scale extinction of different organisms, for example, is already taking place and is clearly irreversible.

Currently, according to researchers, the planetary boundaries or critical environmental limits are already being exceeded on four of the nine dimensions: biodiversity, the global phosphorus and nitrogen cycles, climate change and land use. If the situation is considered from a regional rather than a global perspective, limits are also being exceeded on other dimensions such as water consumption, e.g. in dry regions like the western USA, parts of Southern Europe, Asia and the Middle East.

According to estimates by the International Union for Conservation of Nature and Natural Resources (IUCN), the persistent destruction of species-rich and near-natural habitats is accelerating the speed at which species – along with their genetic information – are being irretrievably lost. Compared with the fossil record, the extinction rate today is substantially higher. Historically, only one mammal species died out per millennium, for example. In the period from the 1970s until today, the rate was 100 to 1000 times higher. By the year 2050 it is likely to have risen once more by a factor of 10. A key reason for biodiversity loss is the progression of land use. Forests continue to be cleared to create farmland, e.g. in South Ame-

2.4 > The planetary boundaries model makes it clear how excessively humankind is overusing resources. The different colours indicate the status of the individual environmental dimensions.



rica or in China and South East Asia. More intensive land use is likely to cause the worldwide area of forest and grassland to shrink by a further 10 to 20 per cent by 2050 – affecting many near-natural habitats along with the species they host.

Nitrogen is important for the production of amino acids, which in turn combine to make proteins. Both plants and animals therefore require nitrogen. In nature, nitrogen occurs as atmospheric nitrogen. Normally, however, higher animals and plants cannot absorb and convert this atmospheric nitrogen directly. Only a few specialized organisms like bacteria are capable of this. In the sea, these include cyanobacteria, single-celled organisms which float freely in the water and used to be known as blue algae. Cyanobacteria absorb atmospheric nitrogen which dissolves in water in the uppermost ocean layers. This is how nitrogen enters marine food webs. Humans make use of nitrogen mainly in the form of artificial fertilizers in agriculture. Particularly in Central Europe and in the agricultural regions of China and the USA, this fertilizer is used excessively and leads to the eutrophication of rivers, lakes and coastal waters, to algal blooms and to the dreaded oxygen depletion.

Amino acids
Amino acids are the building blocks of proteins. In the cells of plants and animals, amino acids are combined into proteins through the complex biochemical process of protein biosynthesis. Depending on their amino acid composition, proteins vary in function. Some are incorporated into muscle mass, others regulate metabolic processes. The central component of every amino acid, known as the amino group, contains nitrogen.

2.5 > Under a microscope, the elongated cyanobacteria resemble strings of pearls. These aquatic creatures, formerly known as blue algae, are capable of processing pure nitrogen.

Climate change is also exceeding the planetary boundary, which is defined as a maximum concentration of carbon dioxide of 350 ppm (parts per million) in the atmosphere. The current concentration of 399 ppm puts this in a danger zone, where a high risk of grave and irreversible environmental change prevails. Climate scientists have long been warning the world that to prevent the worst consequences of climate change, the temperature of the Earth's atmosphere must not be allowed to warm by more than 1.5 to 2 degrees Celsius.

In order to attain sustainability, not only it is necessary to quantify the correct boundaries for each of these environmental dimensions, but comprehensive solutions must also be devised which can be followed through politically, both at regional and supra-regional levels. How difficult that is in the context of the sea can be demonstrated by the long-standing dispute between politicians and fishery researchers over fishing quotas in the European Union. Since the researchers can only estimate quantities of fish, this weak point has frequently been exploited by politicians in order to set higher catch quotas.

The desire for social justice

But the planetary boundaries are just one of the many challenges for future life on Earth. Humankind also finds itself confronted with social problems. Many people are still enduring hunger and living in extreme poverty. The health and education systems in many countries remain severely underdeveloped and in many places there is no social justice. In the past few years the planetary boundaries concept has therefore been refined and supplemented with these social aspects. Only once these social dimensions have also been fulfilled and the critical limits for human society are not being breached will a safe and just space for humankind become a reality. This framework is charted in the image of a doughnut, in which the safe and just space is delimited by the planetary boundaries on the outside and by the essential needs of human beings on the inside. Both the doughnut and the concept of planetary boundaries are so broadly framed that they can be applied to all cultures worldwide. Nevertheless, they do not state in detail what has to be done. To attain the ideal of a safe and just space for humankind, individual habitats must then be examined to see how sustainable use can be achieved in future.

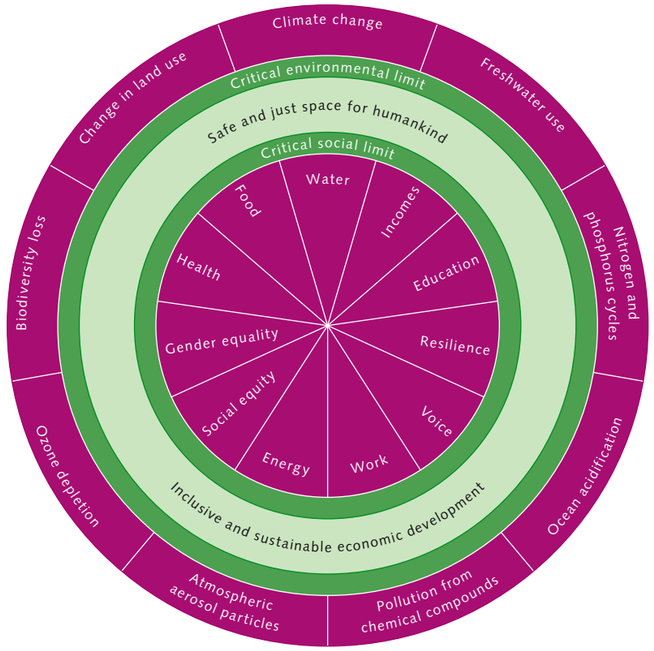
All manner of good

Before ecological limits can be defined, it is necessary to identify which aspects are actually relevant. For instance, the oceans provide special services, many of which are of global importance, and which human beings directly or indirectly use and exploit. Oceans store the energy from sunlight over many months and thus even out seasonal climate fluctuations. Furthermore, ocean currents distribute that heat over thousands of kilometres. The Gulf Stream transports subtropical heat from the Gulf of Mexico across the Atlantic into cooler Europe. Thanks to oceanic heat storage and the Gulf Stream, Europe's prevailing climate is temperate, which is an important prerequisite for its agricultural productivity.

Based on the model of the United Nations Millennium Ecosystem Assessment (MA), a large-scale international project, marine experts have researched marine ecosystem services and allocated them to the four categories of provisioning services, supporting services, regulating services and cultural services. It is not always possible to assign each of the services to a single category. For example, there are some marine assets which represent both provisioning and a cultural service – bivalves, for instance, which are not only sold to the population as vital food but also to tourists as traditional jewellery.

Provisioning services

Among the important provisioning services of the sea from the viewpoint of human beings are oceanic transportation routes as well as the fish and seafood that are existentially important for the nutrition of many millions of people. Around 80 million tonnes per year are fished from oceans worldwide. The value of the annual fish catch amounts to some 115 billion US dollars. Subsequent processing into different fish products, which are likewise



2.6 > The doughnut chart visualizes linkages between the environmental and social dimensions. A safe and just space for humankind emerges within the green-shaded area only, because that is where the critical limits are not being exceeded.

sold, increases value creation in the fishery industry even further. Fish is thus an important economic factor. Around 90 per cent of fishery activities take place in the nutrient-rich and productive coastal areas.

Particularly in the newly industrializing countries, the coastal population often lives directly from the fish catch. According to a scientific study, in 136 out of 144 coastal countries, small-scale fishery in simple motorized, rowing or sailing boats is many people's principal livelihood. In a few regions of Madagascar, up to 87 per cent of adults earn their living from small-scale fishery. Turning to Oceania, 82 per cent of people working in fisheries operate as small-scale fishers – industrial fishery with large trawlers is more or less non-existent there. In such regions fish is particularly significant because in the absence of alternatives it provides both food and incomes at once.

Equally, craft production based on marine animals such as bivalves and molluscs which are processed into souvenirs or jewellery is deemed to belong to the provi-

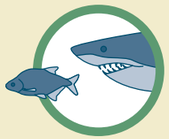
Overview of marine ecosystem services

The advantages and benefits that the oceans provide from the human perspective are referred to as ecosystem services. Ecosystem services can be both material and non-material, and are grouped into four categories.

SUPPORTING ECOSYSTEM SERVICES

can be regarded as the indispensable basis for the other categories of services

Maintenance of intact habitats (by supplying food, oxygen, clean water etc.)

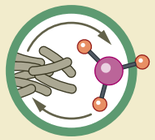


Maintenance of food web dynamics (functioning predator-prey relationships)

Water cycle (evaporation and rainfall; exchange between land, atmosphere and sea)

Safeguarding biodiversity

Primary production (production of biomass)



Nutrient cycles (formation of nutrients through primary production, degradation of nutrients by bacteria and biochemical conversion on the sea floor or in water)

Maintenance of the resilience of marine habitats

CULTURAL ECOSYSTEM SERVICES

comprise diverse functions which serve the non-material well-being of humankind

Contribution to science and to natural history education

Aesthetic value
beautiful marine landscapes

Religious and spiritual value of marine landscapes and places near and in the sea

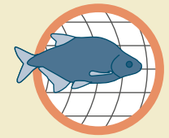
Inspiration for folklore, art, architecture etc.

Recreation and tourism

Cultural heritage (culturally significant landscapes and places near and in the sea, culturally significant sea creatures for traditional jewellery etc.)

PROVISIONING ECOSYSTEM SERVICES

encompass products and goods for direct human sustenance, on the one hand, and spaces and areas that the sea makes available, on the other

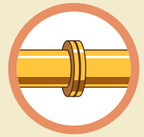


Fish and seafood from wild catch and aquaculture

Transportation routes

Renewable energies (tides, waves and wind)

Drinking water from seawater desalination plants



Areas for pipelines and sea cables

Pharmaceutical ingredients and other biochemical substances, e.g. for the food and cosmetics industry

Goods for jewellery or souvenirs

Areas suitable for military use

Non-renewable resources (natural gas, oil, gravel and sand)

Genetic resources from bacteria, sponges, and other organisms, e.g. for the development of new medicines

REGULATING ECOSYSTEM SERVICES

comprise the advantages and benefits that humankind gains from the regulating effect of the sea and its ecosystems

Coastal protection by dunes, coral reefs and mangrove forests

Climate regulation through the transportation of heat by ocean currents and heat exchange between water and atmosphere

Maintenance of water purity by breaking down nutrients from wastewater and agriculture which enter the sea

Maintenance of air quality through algal production of oxygen or ocean uptake of carbon dioxide

Maintenance of water purity by breaking down pollutants by means of dilution, chemical modification into harmless substances, or sinking and burial in the sediment

sioning services of the oceans. In many cases, even today substances from the sea are already being used for cosmetic products or in the chemical industry. Chitosan extracted from crab shells, for instance, is mixed into dental-care products because it protects the tooth enamel.

Another aspect of growing interest is the medical potential of marine organisms as well as their genetic information. Substances which combat herpes or malignant tumours have been isolated from poriferans (sponges). Moreover, in future scientists hope to isolate genes which contain the assembly instructions for proteins of medicinal interest. If genes like these can successfully be transferred into cultures of industrially-used bacteria like *Escherichia coli*, the active substances can be manufactured on a grand scale. There are also prospects of isolating new antibacterial substances from marine organisms which prove effective against the dreaded multi-resistant germs that can no longer be treated with conventional antibiotics.

The seas also offer a range of other provisioning services. Among them are the non-renewable energy sources of natural gas and petroleum, the ores on the sea floor, and diamond deposits. Sand which is dredged from offshore to replenish sandy beaches after severe storms or for use on building sites is another such service, as are the transportation routes that the sea provides for shipping.

The sea not only provides energy in the form of fossil fuels but also in the form of renewable resources. Today there are increasingly vigorous efforts to mobilize the energy that is latent in waves, in tidal currents and in the wind over the sea. Some time ago on the Irish coast, an underwater propeller was installed which is set in motion by the rise and fall of the tides. Another notable technology is the Pelamis wave energy converter which floats on the sea like a sea snake. It consists of several segments which move against each other, generating hydraulic pressure. This in turn powers a turbine. There are now several Pelamis installations in operation off Portugal and in the Orkney and Shetland Islands. Experts estimate that 1700 terawatts of electricity per year could be generated from wave energy alone, which equates to about 10 per cent of global electricity demand. The number of wind turbines in the sea is also increasing. The country leading the way in offshore wind energy is Great Britain, where a good dozen large-scale wind farms have been constructed off the coast.

2.7 > Fishers on the beach at Kayar, Senegal. In their pirogues, boats made from a single tree, they put out to sea in order to supply local markets with fish. Tens of thousands along Senegal's coast engage in "la pêche artisanale" – artisanal fishing.

Cultural services

Cultural services are those which have particular social, religious or spiritual significance or which are part of a nation's traditions. Beyond this, cultural services encompass the aesthetics of a landscape and its recreational function, leisure value or the inspiration that it provides. Likewise, a marine area's appeal for science or natural history is deemed by sustainability experts to belong to cultural services. It is perfectly possible for these to overlap with other ecosystem services – for example, with the provisioning services.

A historical example is the pigment purpura, which was a briskly traded commodity in ancient times. In those days the pigment was extracted mainly in Greece from the purple dye murex, a species of sea snail. Since each mollusc contains a tiny amount of pigment, lots of the creatures are needed, which makes production time-consuming and expensive. The extracted purpura was an exclusive product and was, for a long time, reserved for dignitaries and high officials. Therefore it was also high in symbolic value. In Rome, for example, the members of the Senate decorated their togas with purple borders. The purpura trade was a profitable business for centuries.

Another natural product which for a long time embodied great meaning and considerable wealth was pearls, which were obtained in the Persian Gulf by pearl divers. For many years the pearl trade was the most important economic branch in this region. At the beginning of the twentieth century the pearl industry was in its final flush of success. The annual turnover of pearls was valued at 160 million US dollars. Not long after that, however, the Japanese succeeded in breeding pearl oysters in large quantities. This broke the monopoly of the pearl divers around the Persian Gulf.

2.8 > The purple dye murex *Bolinus brandaris*. The purple dye was extracted from a whitish secretion in the mantle cavity. 8000 of the molluscs were necessary in order to produce 1 gram of the dye. 200 grams of dye were needed to dye 1 kilogram of wool.

Unlike purpura and pearls from the Persian Gulf, sharkfin soup is still of significance even today. The dish is a traditional delicacy in Chinese-speaking regions in particular. Today the soup is offered at very high prices. It not only serves as food but also symbolizes prestige and status, which makes it both a provisioning and a cultural service at once.

Shark fishing is highly contentious, however. Because it is very profitable, sharks – including threatened species – are hunted intensively and some populations have diminished drastically as a result. Furthermore, in many cases the captured animals are not fully utilized. Often only the valuable fins are removed and the cadavers are thrown back into the sea, unused.

A different situation is faced by the Nuu-chah-nulth people, First Nation people living on and around Vancouver Island on the Canadian Pacific coast. They used to hunt whales, but today that is prohibited for species conserva-

2.9 > Oostduinkerke in Belgium still has a few fishers who catch shrimps using a very peculiar method. They sit on a horse, which drags the heavy shrimping nets along behind it.

tion reasons. The Nuu-chah-nulth people perceive the ban as the painful loss of a tradition, for the whaling, the collective hunting, the butchering of the animals and the traditional festivals which accompanied whaling fostered the community of First Nation people fundamentally. Once whaling was banned, this important social bonding element went missing. This case makes clear how complex it can be to evaluate cultural ecosystem services.

An example of the sea's religious and spiritual aspects is sea burial, which is commonly practised in Europe and Japan. Many people express the wish not to be buried in the ground but in the open sea, the origin of all life. After the cremation of the body, the ashes are consigned to the sea in a water-soluble urn. This type of burial is only allowed in certain sea areas. Furthermore, it is only possible because the 1972 Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (shortened to: London Convention, LC) permits the committal of urns as an exception.

Also of cultural importance today is the old tradition of Lenj boat-building that is still practised in Iran. The roughly 15-metre-long wooden boats have long been used along the north-east coast of the Persian Gulf for trade, travel, pearl diving and fishery. Numerous folk tales have grown up around the Lenj boats. Today, artists also maintain the tradition, and certain places organize their own Lenj festivals.

UNESCO (the United Nations Educational, Scientific and Cultural Organization) has placed Lenj boat-building on its intangible cultural heritage list. Other assets on this list include the traditional Belgian form of prawn or shrimp fishery which makes use of heavy work-horses. The cart-horses drag fishing gear through the water parallel to the beach. For decades the vast majority of shrimps in Western Europe have been fished from cutters, but on the Channel coast near Oostduinkerke there are still families who hold on to the laborious tradition with the horse. The catch yielded by the horse-drawn technique is just enough to live from, say the fishers. Its economic significance for the region is more or less negligible.

Currently the UNESCO list contains a total of 42 marine and coastal areas or associated traditions.

Cultural services – Basis for tourism

Aspects like the recreational value or the beauty of a coastal landscape, which are categorized as cultural ecosystem services, are closely associated with tourism. Religious sites and other cultural monuments, landscapes of natural beauty and recreational areas attract millions of holidaymakers every year. The number of people who take seaside vacations and the resultant importance of coasts for global tourism can barely be quantified at the moment, according to the United Nations World Tourism Organization (UNWTO), because the data is gathered in different ways in different regions or is incomplete. Added to that, it is almost impossible to analyse the extent to which the hinterland also benefits from coastal tourism – when beach holidaymakers visit the inland towns, for example. Nevertheless, in Europe the attempt is made to gauge the proportion of tourists staying in coastal regions. It is estimated that in 2009 some 28 million bed spaces were available in total (in holiday apartments, hotels, hostels or on campsites) in 27 European countries. Of these, around 60 per cent were located in the coastal regions. According to a survey conducted in the European Union (EU), 46 per cent of EU citizens spend their annual

2.10 > In the past, Iranian Lenj wooden boats were used along the Persian Gulf for trading, pearl diving or fishing. UNESCO wants to preserve the tradition of Lenj boat-building.

holiday as beach tourists. These statistics did not take account of tourists who head for the sea to pursue diving or other sporting activities. This in turn means that the total number of EU maritime holidaymakers may be even higher.

The UNWTO cites whale- and dolphin-watching tours as an example of the sea's popularity with tourists. This is one segment of tourism for which sufficient data exists. Whale-watching expeditions were first offered early in the 1950s on Point Loma peninsula in California. In those days the sea mammals were only observed from the shore. Even at that time the whales attracted around 10 000 visitors a year. It turned out that people elsewhere found the large animals equally fascinating, and eventually this tourist attraction spread around the whole world. Today whale- and dolphin-watching tours are offered in 119 countries. Around 13 million people per year take up such offers, spending around 800 million US dollars on the pastime. Once the costs of accommodation, travel and meals are taken into the calculations, the expenditure of these tourists amounts to 2.1 billion US dollars per year.

2.11 > The limestone caves on Mexico's Yucatán peninsula are very popular with divers.

Region	Whale and dolphin watchers in 2008	Countries in 2008	Direct spending (USD million)	Total spending (USD million)
Africa and Middle East	1 361 330	22	31.7	163.5
Europe	828 115	22	32.2	97.6
Asia	1 055 781	20	21.6	65.9
Oceania, Pacific islands, Antarctica	2 477 200	17	117.2	327.9
North America	6 256 277	4	566.2	1 192.6
Central America and Caribbean	301 616	23	19.5	53.8
South America	696 900	11	84.2	211.8
GLOBAL TOTAL	**12 977 218**	**119**	**872.7**	**2 113.1**

2.12 > Whale- and dolphin-watching are an important segment of the tourism industry. In 2008, almost 13 million people worldwide went on such safaris, spending 2.1 billion US dollars on these tours including travel and accommodation.

Supporting services

Biological, chemical and physical processes that take place naturally in the environment and are thus the basis of life on Earth are categorized as supporting services. This category also includes the dynamics of the marine food web. Its finely balanced coexistence of predators and prey is ultimately of great benefit to humans, too, since fish is a valuable foodstuff.

Even the biodiversity of habitats and the different habitats themselves are classified as supporting services. Scientists have established that species diversity is extremely important for the stability of marine ecosystems. This has been demonstrated in various ways including experiments in macro-algae forests. In one field experiment, for example, the number of macro-algae species was artificially reduced by removing several species at the beginning of the growth period. In this species-impoverished habitat the overall algae biomass did actually diminish – reducing the availability of food for consumers and the number of available habitats.

One significant supporting service for marine life is the process known as primary production, the basis of which is photosynthesis by phytoplankton. Photosynthesis is the way in which plants make use of sunlight to create energy-rich molecules like sugar and starch. With the right light intensity and food supply, algae can grow and multiply very quickly. The service provided by marine algae is remarkable: all in all they produce around 50 per cent of the plant biomass worldwide.

Primary production is the basis of the food web. Unicellular algae are eaten by fish larvae and micro-crustaceans, which in turn become food for larger fish or sea mammals. The importance of primary production in the sea is shown by studies which have investigated the degree to which the size of fish stocks correlates with primary production. It emerged that in areas of periodically high primary production, the quantity of fish caught could rise by up to 30 per cent, whereas in other regions it decreased by up to 40 per cent in times of low primary production.

Primary production is bound up with the various biochemical processes and biogeochemical cycles of the sea. One example of these fundamental processes in the ocean is the carbon cycle. Carbon is the basic component of the human body and constitutes the vast majority of animal and plant biomass. Land-based plants and sea algae take it up from the atmosphere or the water in the form of carbon dioxide (CO_2). The plants then make use of the CO_2 as a component for sugar and starch production during photosynthesis. Through the metabolism of organisms and by means of natural chemical processes, carbon is constantly changing its state. In the sea, for instance, large quantities of carbon in the form of dead and decaying biomass, e.g. algae or micro-crustaceans, drop down into deep waters, but even while it is sinking some of this carbon is already being re-used by bacteria as food, and thereby metabolized.

Alongside the carbon cycle, a range of other cycles are significant to life. One example is the nitrogen cycle.

Regulating services

The protection from storms and floods afforded by mangrove forests, dunes, or coral reefs come into the category of regulating services, as does protection from erosion, i.e. the loss of sand from the coastline caused by storms and currents. This kind of protection is provided by intact ecosystems, such as the dense vegetation on dunes which holds down the sand during storms, or **seagrass meadows** and mussel beds in the water which prevent the fine sediment from being carried away by waves.

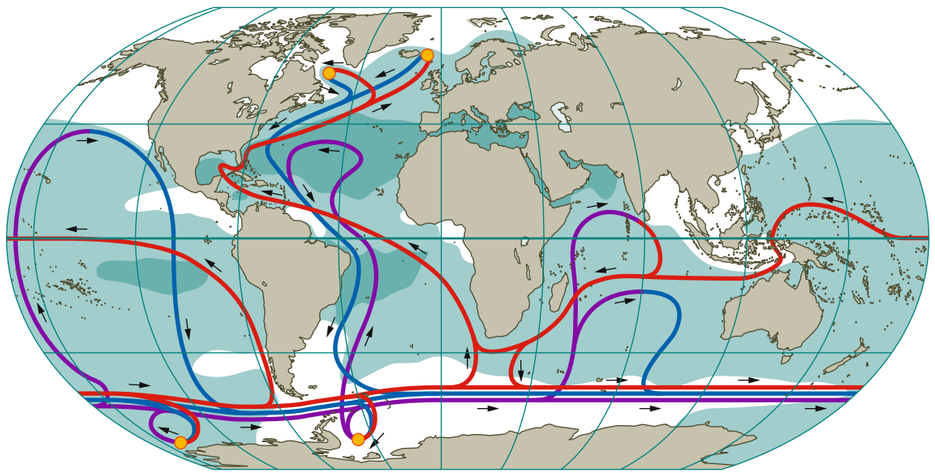
Large quantities of waste and excrement find their way into the sea from rivers or are piped from the sewage system directly into coastal waters in many places. Biodegradation of this matter is likewise considered a regulating ecosystem service, as is the absorption of toxic substances released by humans, e.g. heavy metals or persistent chlorine and fluorine compounds. Single-celled organisms and bacteria are the main biodegraders of this organic pollution load. When they die and drop to the sea floor, the pollutants settle along with them, accumulate in the sediment and are thus removed from the water. Naturally, the toxic substances in the sediment still persist in the environment for a long time, but had they remained

in the water many marine organisms would have been directly exposed to them. Plankton organisms especially would have absorbed these pollutants from the water along with tiny particles of food and then passed them on to other organisms in the food chain.

Engine of the climate system

The sea has a decisive influence on the climate. Scientists even refer to it as the engine of the Earth's climate system. Firstly, the sea exerts a regional influence. Since it can store heat for long periods, in winter it heats up the atmosphere and thus brings warmer air onto dry land in coastal areas. Because a great deal of water evaporates over the sea, in many regions the oceans also supply a large proportion of the rain that falls over the land.

Secondly, the sea has a global climate effect. The seawater in the tropics absorbs large quantities of solar energy and transports this towards the poles. Water can store heat energy for long periods so that the energy is transported over many thousands of kilometres. But the sun over the tropics is not the only driving force. Physical processes at the poles also keep the global climate machine in motion: There the water cools drastically so that ice forms. Since ice contains no salt and the salt is left behind in the seawater on freezing, in areas of sea ice the salt content of the water rises. The high salt content and the chilling make the seawater denser and thus heavier. Consequently the water begins to sink downwards. This phenomenon, which occurs in just a few polar sea regions, is known by experts as convection. Below about 2000 metres the water stratifies into the deep water masses and flows very slowly back towards the equator. This completes the loop of the large ocean currents, which begins in the tropics. Since these currents which encircle the globe are driven by temperatures and salt content, scientists call this phenomenon thermohaline circulation (*thermo*: driven by temperature differences; *haline*: driven by salt-content differences). But thermohaline circulation is not the only influence on ocean currents; the winds also have an effect.



2.13 > The global currents that flow around the world are complex and connect all the oceans. The diagram shows the thermohaline overturning circulation in simplified form. The yellow circles represent the most important areas where water sinks to a great depth. The purple and blue lines radiating from them mark the paths of the surface and deep-water currents. On their way through the ocean, these currents are mixed and warmed until they finally rise upwards. The paths of the warm return flows, which are close to the surface, are shown in red. Surface salt content is higher in the dark areas and lower in the white areas. Since the Atlantic is more saline than the Pacific on average, deep water can form there more easily. The circumpolar current shows that all oceans are interconnected.

Winds arise because sea areas or different landmasses heat up unevenly. This gives rise to differences in atmospheric pressure which are evened out by wind currents. The trade winds, which blow from the same direction for several months in the tropics and subtropics, are a major influence. In certain areas the trade winds drive the surface water away from the coasts. Consequently cold and nutrient-rich water from the depths rises towards the surface along the coast. Experts call these sea regions upwelling areas. Examples are the coastal waters off Peru and South Africa. Since the upwelling water brings many nutrients from the deep sea to the surface, primary production is particularly high in these waters, and they are especially rich in fish.

Exchange of gases

Not only the climate but also gases are regulated by the sea; the oceans and the atmosphere are permanently exchanging large volumes of gases. Every day, for example, seawater absorbs quantities of carbon dioxide equivalent to the weight of four million mid-range cars. Since the beginning of the Industrial Revolution, the oceans have swallowed up around half of the total carbon dioxide (CO_2) released by the burning of natural gas, petroleum and coal. Without this constant CO_2 uptake, the atmosphere would have been subject to far greater warming than has actually occurred.

Apart from CO_2 a range of other gases pass back and forth between ocean and atmosphere; for example, nitrogen and methane.

Algae odour acts as cloud seed

For the last few years researchers have also been taking an interest in a gas that was long disregarded: dimethyl sulphide. It arises when dead algae decompose, and causes the typical odour given off by algae on the beach. Scientists have found out that dimethyl sulphide is emitted in large quantities from the sea into the atmosphere, where it plays an important part in cloud formation as a condensation nucleus. Since clouds reflect sunlight and to some extent also thermal radiation, scientists suspect that dimethyl sulphide has a significant bearing on the climate. This is why producing dimethyl sulphide and exchanging it between water and air is now also considered to be one of the ocean's regulating ecosystem services.

Responsibility for future generations

The regulating and supporting services of the sea are particularly significant for life on Earth because they are comprised of some fundamental biological, biochemical and physical processes. These processes have been going on for millennia and some of them respond very sluggishly to changes. This is particularly true of the ocean's role as the engine of the climate system.

Ocean currents are constantly turning over immensely large water masses but move very slowly for the most part – often at slower than walking pace. The deep water that has sunk to the poles during thermohaline circulation moves so slowly that it remains at depth for several hundred to 1000 years. As a result of this, so far the human-induced changes to the climate which are causing the seawater to warm up are mainly detectable at the sea surface. It will still take some time before climate change really penetrates the ocean depths. Not that this is any reason for complacency. It means that changes affecting regulating and supporting ecosystem services of the ocean carry special weight as an intergenerational issue. Changes caused by human activity today could still be affecting people's lives in several hundred years time.

In view of the great importance of the sea's regulating and supporting ecosystem services, sustainability experts are now making the case that the Gulf Stream or the carbon cycle might also be considered as critical natural capital or critical services. The most important task for the future is therefore to develop strategies to safeguard these critical and other marine ecosystem services for the future, in the context of sustainable development.

Oceans under threat

> Humankind has been damaging the seas for decades by discharging pollutants into the water, destroying coastal ecosystems and overexploiting fish stocks. Ocean warming and ocean acidification are new global-scale threats affecting the seas today. A precondition for sustainable ocean use will be an exact analysis of its condition so as to allow for the correct environmental policy measures to be taken from now on.

Multiple causes of the oceans' critical state

Be it overfishing, marine pollution, ocean warming or acidification – today the oceans and the ecosystem services they provide are under more serious threat than ever before. The many problems caused by either regional mismanagement or global climate change render marine protection a particular challenge, which can only be met by a multitude of individual measures.

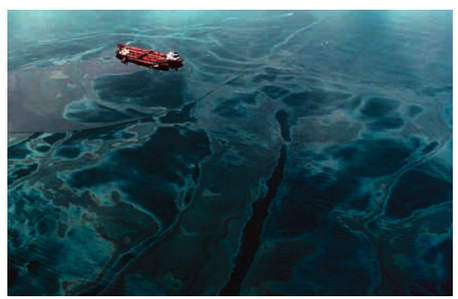
Coastal regions are acutely affected as they are particularly densely populated and coastal seas are subject to intensive use. The bulk of fish are taken from coastal waters which are, moreover, the focus of drilling for natural gas and crude oil as well as intensive shipping transport. Tourism is another particular threat to coastal areas. Many coastal regions are popular holiday destinations, which often results in natural areas in these regions being destroyed for the sake of constructing hotel complexes.

The recognition and correct assessment of individual threats is a precondition for future sustainable ocean use. This is not always an easy feat. It is relatively easy to estimate the degree of pollution caused by a damaged oil tanker. However, it is almost impossible for researchers to determine the likely impacts of the insidious process of ocean acidification on different groups of marine life such as fish, bivalves, or molluscs.

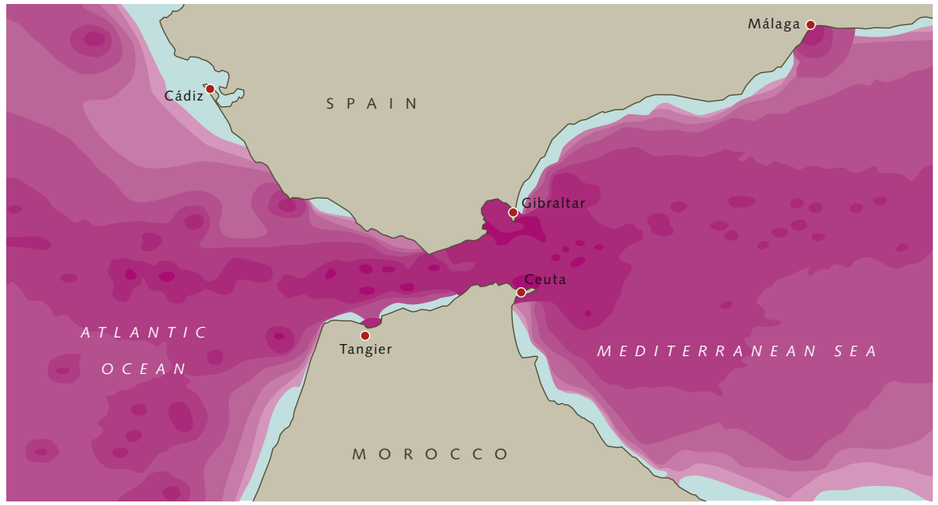
In recent years, marine scientists have tried to identify and categorize the various aspects responsible for the mounting adverse impacts on our oceans.

The following threats and pressures are of particular significance:

- **Marine pollution**
  - Toxic substances and heavy metals from industrial plants (liquid effluent and gaseous emissions);
  - Nutrients, in particular phosphate and nitrogen, from agricultural sources and untreated wastewater (eutrophication of coastal waters);
  - Ocean noise pollution from shipping and from the growing offshore industry (exploitation of oil and natural gas reserves, construction of wind turbines, future mineral extraction).
- **Growing demand for resources**
  - Exploitation of oil and natural gas reserves in inshore areas and increasingly also in deep-sea areas, resulting in smaller or greater amounts of oil being released into the sea;
  - Sand, gravel and rock for construction purposes;
  - For the development of new pharmaceuticals: extraction of genetic resources from marine life such as bacteria, sponges and other life forms, the removal of which may result in damage to sea-floor habitats;
  - Future ocean mining (ore mining at the sea floor) which may damage deep sea habitats;
  - Aquaculture (release of nutrients, pharmaceuticals and pathogens).
- **Overfishing**
  - Industrial-scale fishing and overexploitation of fish stocks; illegal fishing.
- **Habitat destruction**
  - Building projects such as port extensions or hotels;
  - Clear-felling of mangrove forests;
  - Destruction of coral reefs as a result of fishing or tourism.
- **Bioinvasion**
  - Inward movement of non-indigenous species as a result of shipping transport or shellfish farming; changes in characteristic habitats.
- **Climate change**
  - Ocean warming;
  - Sea-level rise;
  - Ocean acidification.



2.14 > When in 1989 the oil tanker *Exxon Valdez* ran aground near Alaska, the oil eventually covered 2000 kilometres of coastline. Several nature reserves and protected areas for birds are located in the area.



2.15 > Oceans are also affected by noise pollution. In 2014, French scientists for the first time produced a map depicting noise pollution in the Strait of Gibraltar which is subject to high levels of shipping traffic. The depth of the red colour indicates the noise level – the deeper the colour, the noisier the area.

Global threats

These threats have not diminished in recent year. One exception is oil pollution where changes for the better are evident: There has been a decrease in the amount of oil entering the oceans. Moreover, in Western Europe fewer nutrients are reaching the North Sea. However, for most of the other pressures there is no sign of a reversal of trends. Quite to the contrary, the threats are actually increasing.

Many scientists take the view that ocean warming and ocean acidification, two of the effects of climate change, are having a global impact on the oceans. The cause of seawater becoming more acidic is the increase in atmospheric carbon dioxide (CO_2), some of which enters the ocean, thus increasing dissolved CO_2 in the seawater which leads, simply put, to the formation of carbonic acid. Laboratory experiments have shown that more acidic water renders calcium carbonate ($CaCO_3$) structures of oceanic calcifying organisms, such as corals, bivalves, molluscs and sea urchins, more vulnerable to dissolution. There are a number of naturally occurring forms of $CaCO_3$ which differ minimally in their chemical composition, such as aragonite and calcite, two forms of $CaCO_3$ used by a range of marine organisms at different proportions to construct their shells or exoskeletons. The experiments have shown that those animal species which primarily use aragonite are likely to be the first to be most strongly affected by ocean acidification.

In particular, the zooplanktonic pteropods may be affected in the future; these are pea-sized "wing-footed" free-swimming sea snails. Pteropods are an important

2.16 > The pteropods' thin and fragile calcified shells may dissolve as a result of ocean acidification.

food source of fish as well as whales. Their aragonitic shells are particularly delicate and marine scientists are concerned that these shells may dissolve very quickly. Studies have shown that ocean acidification is a threat even to their offspring which may perish during their growth phase. But the shells of adult pteropods also dissolve over time.

As gases such as CO_2 dissolve more readily in cold water, ocean acidification proceeds most rapidly in the colder waters of higher latitudes. In cold waters, marine scientists are already seeing the first signs of the critical point slowly being exceeded at which aragonite is beginning to dissolve. For example, on expeditions conducted by the United States National Oceanic and Atmospheric Administration (NOAA) in the Pacific Ocean off the northern U.S. states of Washington and Oregon, numerous adult pteropods were caught the shells of which displayed clear signs of corrosion.

The ongoing process of ocean acidification also impacts on animal behaviour. Scientists have found that the Atlantic king scallop loses its ability to escape from predators. Normally the animals' escape strategy involves fast shell closure and jet-like propulsion enabling them to swim out of the danger zone. With increasing acidification, however, this clapping performance weakens, thus compromising their ability to escape from predators.

What is worrying is that the two phenomena of ocean acidification and ocean warming can amplify each other. Laboratory experiments conducted by ecophysiologists studying animal metabolism have shown that some crustaceans and fish have a shortened lifespan if the water becomes both warmer and more acidic at the same time.

Coastal hotspots

While not all marine regions are threatened by the same environmental problems, coastal regions in particular, counting amongst the world's most densely populated areas, tend to be affected by a multitude of problems at the same time. Comprehensive marine protection in these regions would benefit a huge number of people. The United Nations estimate that today more than 40 per cent of the world's population, i.e. more than 2.8 billion people, live within 100 kilometres of the coast. Thirteen of the world's 20 megacities containing 10 million or more people lie along coasts. These include the cities or conurbations of Beijing (14.3), Calcutta (14.3 million), Dhaka (14.4), Istanbul (14.4) and Mumbai (18.2). Experts expect further increases in the urbanization of coastal areas over the coming years. They anticipate, for example, that in West Africa the 500 kilometres of already densely populated coastline between Ghana's capital Accra and the Niger delta in Nigeria will become a continuous urban megalopolis of more than 50 million inhabitants by 2020.

The hinterland's significance for the coast

The state of the coastal seas is dependent on both the activities taking place directly on the coast and on impacts exerted by the coastal hinterland. Some problems arise directly on the coastline, such as untreated effluent discharge or the destruction of the coastal strip as a result of building construction. But in many regions, large quantities of pollutants also arise in the hinterland, reaching the coast via rivers or the air to be discharged into the coastal seas. These pollutants may originate far inland. The chemically highly stable fluoropolymers, for example, which are used for the production of outdoor jackets as well as grease, dirt and water-repellent paper, are released into the atmosphere from factory chimneys and travel thousands of kilometres into far distant regions. Similarly, the journey of sewage or industrial effluent contaminated with heavy metals often begins far inland. Experts estimate that land-based sources now account for 80 per cent of marine pollution including fertilizers.

It is in fact very difficult to define a clear boundary between the coast and its hinterland – where does one end and the other begin? Indeed, there is no universal definition of the term "coast". Scientists in different fields use different criteria of relevance in this respect. Geologists may look at sediment transport from the mountains or the hinterland into coastal waters, whereas botanists researching salt marsh vegetation might have a more narrow definition of what constitutes the coast.

2.17 > A slum in Ghana's capital Accra. The 500 kilometres of coastline between Ghana's capital Accra and the Niger delta in Nigeria is expected to become a continuous urban megalopolis of more than 50 million inhabitants by 2020.

The sum of many threats: the coastal syndrome

Considering the accumulation of environmental problems on the coasts, environmental scientists have coined the term “coastal syndrome”. They use this term to demonstrate that coastal waters in many regions are showing symptoms which indicate that their ecosystem functions and services have been compromised. The scientists take into account impacts on coastal waters arising in the hinterland as well as impacts arising directly on the coast. The following aspects contribute to the coastal syndrome:

Eutrophication

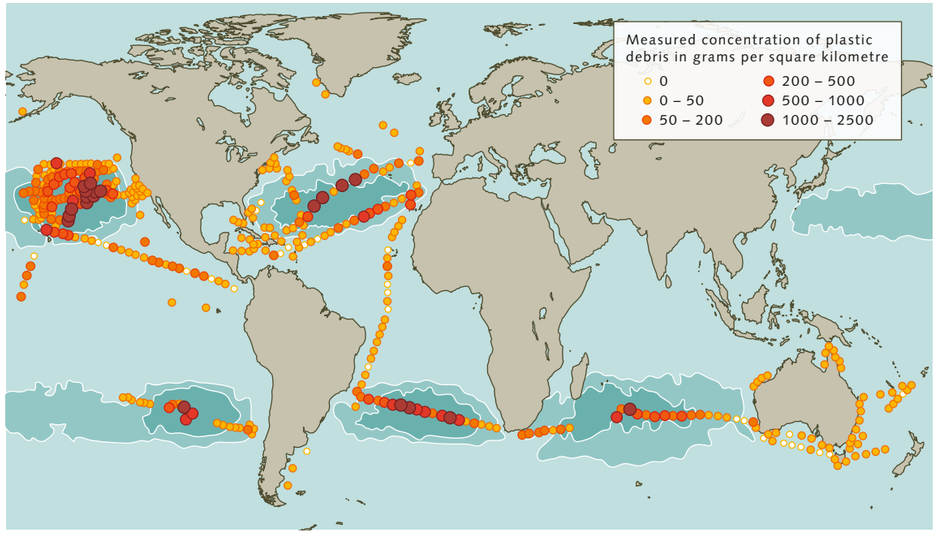
In regions that are subject to intensive agricultural practices, a lot of nutrients enter the soil. These nutrients are landspread in the form of chemical fertilizers or slurry from livestock production units. Moreover, municipalities may discharge similarly nutrient-rich untreated wastewater and, in particular, excrements. By way of streams and rivers or the sewage system, excess nutrients are transported all the way to the sea. Phosphorus and nitrogen compounds in particular encourage strong algal growth, resulting in algal blooms. Ultimately, oxygen-consuming bacteria decompose dead algae. The more algae are present, the more intensive the process of bacterial degradation and the greater the oxygen demand. In extreme cases anoxic zones may result in which fish, crustaceans or bivalves can no longer survive. Examples of highly eutrophied marine areas are the Mississippi Delta at the Gulf of Mexico or the Yellow Sea on China’s east coast.

Owing to high levels of nutrient runoff from agriculture carried by the Mississippi River, a “dead zone” has developed in recent years off the U.S. state of Louisiana, reaching a size of up to 20 000 square kilometres.

In the Yellow Sea which is located between mainland China and the Korean Peninsula, massive algal blooms have become an annual occurrence since 2007. Each summer the seaweed *Ulva prolifera* produces a thick green floating carpet on the water surface. In the summer of 2008, the algal carpet reached an unprecedented size, swathing approximately 1200 square kilometres – twice the extent of Lake Geneva. At the height of the summer season and during the Olympic sailing events, the algal carpet floated to the Chinese urban centre of Qingdao. City officials had to remove about one million tonnes of biomass from the local beaches alone. In a recent study, Chinese scientists concluded that the amount of nutrients discharged into the Chinese coastal waters of the Yellow Sea had increased by an average of 45 per cent in the 2007 to 2012 period compared to the years 2001 to 2006.

Research conducted in Germany has shown that it is possible to reduce the nutrient load, at least in part. Annual phosphate inputs into the North Sea watershed declined from approximately 67 000 tonnes in 1985 to 18 000 tonnes in 2005 as a result of a ban on the use of phosphorus in detergents, improved wastewater treatment in sewage plants, and optimized phosphate fertilizer applications. Over the same period, nitrogen inputs declined from 804 000 tonnes to 418 000 tonnes annually, primarily due to optimized fertilizer application technology. Fertilizer usage in general has improved in recent decades, with more farmers now choosing optimum timing for fertilizer applications and more products now being on the market which facilitate improved plant uptake. As a result, lesser amounts of fertilizer remain in the soil which could leach out with rainfall.

2.18 > Algal bloom at the Chinese coastal city of Qingdao. Helpers use fishing boats to gather up the thick green mass. Algal blooms have been occurring in the region for about the past decade. Scientists blame high levels of nutrient deposition into the sea.



2.19 > The world’s oceans are polluted with varying concentrations of plastic debris. The highest concentrations of 1 to 2.5 kilograms per square kilometre can be found in the major ocean gyres, and especially in the North Pacific Ocean.

Pollution

Two intergovernmental conventions provide for internationally mandatory marine protection: The Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972 (London Convention, LC) and the 1996 London Protocol (LP) to the Convention, which strengthens and gives more concrete expression to the Convention’s provisions. Nonetheless the situation of many coastal regions continues to be very poor. Large quantities of a whole range of pollutants continue to reach the oceans, such as pollutants contained in untreated wastewater or exhaust air discharged from industrial plants, crude oil associated with the routine operation of drilling platforms or oil spills resulting from tanker accidents, as well as plastic litter. Plastic litter is largely landborn. Especially in areas where there is no well-organized refuse collection, litter is washed down rivers or the wind blows rubbish straight into the sea.

Along highly frequented shipping routes, such as the English Channel, ship waste accounts for a high proportion of ocean plastic litter. Global figures on the annual input of marine litter are nothing more than vague estimates. In 1997, the US Academy of Sciences estimated the total input of plastic litter into the oceans, worldwide, at approximately 6.4 million tonnes per year. This figure is likely to have risen since.

Plastic litter does not only pollute coastal waters. Much of it becomes concentrated in the middle of the oceans where major sea currents converge and swirl in immense spirals which basically become flotsam-collecting vortexes. The largest of these areas is the Great Pacific Garbage Patch. Just how dense the concentration of litter is in this region became evident during the dramatic search for debris from Malaysia Airlines passenger flight MH370 that vanished in the Pacific Ocean on 8 March 2014. For many days, specialists attempted to spot aircraft debris using planes and satellite imagery. One false report chased another, as the searchers mistook sea trash for possible aircraft parts.

Destruction of coastal habitats

Coastal habitats, which continue to be destroyed, include wetlands, salt marshes and mudflats, coral reefs and mangrove forests. Causes of their destruction differ between regions. Wetlands, such as certain sea bays or mudflats, often fall victim to construction projects, land reclamation

2.20 > Coral reefs, such as the one pictured here in the Red Sea off Egypt, are of major significance due to their species diversity. Coral reefs worldwide host somewhere between one and three million different species. However, today these ecosystems face multiple threats.

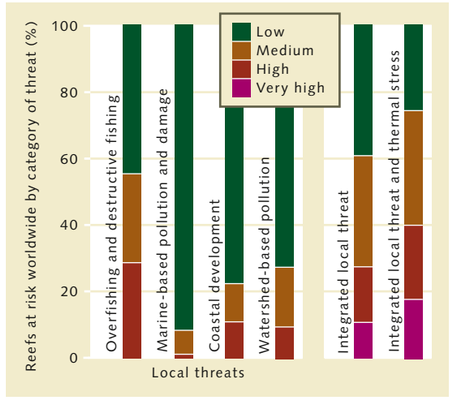
or coastal impounding. For example, in 2006 a 33 kilometre long seawall was completed for land reclamation purposes which cut the Saemangeum estuarine tidal flat on the South Korean coast off from the sea. Until that time, the bay had contained the world's third most extensive area of mudflats (after the Wadden Sea on the Danish, German and Dutch coast, and the Bay of Fundy on the Canadian Atlantic coast). As a result of the seawall project approximately 400 square kilometres of mudflats were lost, an area roughly equivalent to the size of the Greek island of Naxos. While there are floodgates allowing water to discharge from the bay, the regular tidal currents have been disrupted, and with this the tidal flats have disappeared. In the past, Saemangeum had been one of the most important resting areas for a range of migratory bird species that breed in Siberia and overwinter in South East Asia. With the estuarine mudflats having been dammed, many birds lost this critical feeding area. Some of the rare migratory bird species have suffered major population declines as a result.

Similarly, many coastal wetlands around the world have been or are being destroyed. One such example are the salt marshes and reed beds in San Francisco Bay. The area is roughly the size of Manhattan and it constitutes the largest wetland on the West Coast of the United States. As much of the area has been dissected or covered by roads, bridges and settlements, a mere 8 per cent remain in a natural condition. The Sacramento Fish and Wildlife Office has now completed a management plan aimed at restoring parts of the bay.

Tropical coral reefs are also under threat. Covering only about 1.2 per cent of the world's continental shelf area, they are highly biologically diverse ecosystems. Estimates of the total number of species of fish, bivalves, corals and bacteria on tropical coral reefs range from one million to three million. Approximately one quarter of all marine fish species inhabit tropical coral reefs. Experts have estimated that about 20 per cent of tropical coral reefs have been destroyed; a further 30 per cent have suffered serious damage. More than 60 per cent of all tropical coral reefs are currently facing at least one of the following threats from local sources:

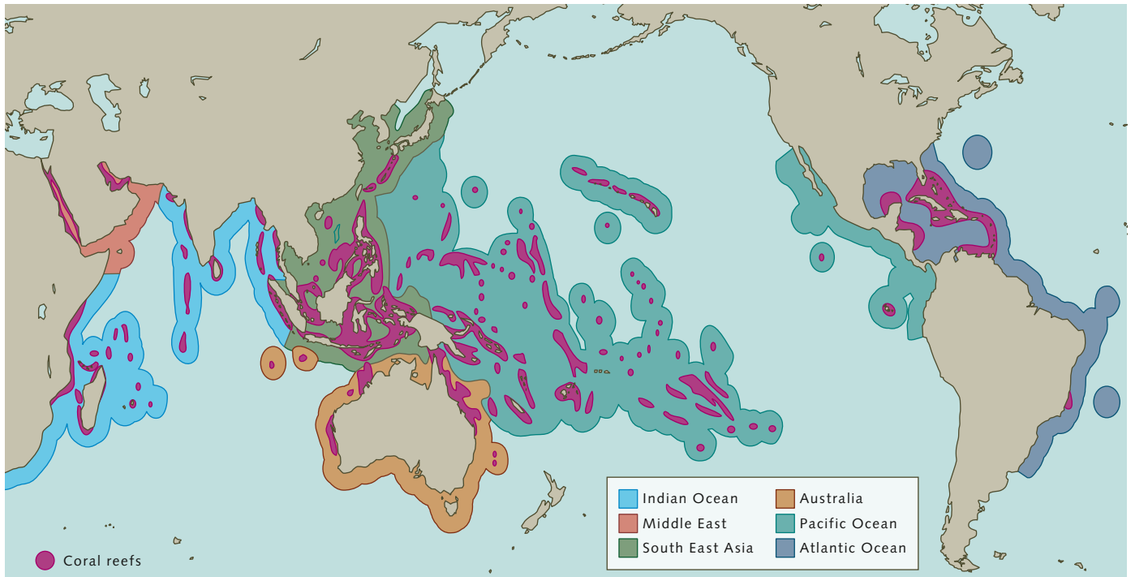
- Destruction as a result of overfishing or destructive fishing methods resulting in severe damage to corals;
- Coastal development (construction projects);
- Pollution of the seawater as a result of pollutants and sediments discharging into the marine environment from rivers;
- Pollution of the seawater at the local level as a result of direct discharges of wastewater on the coast or from commercial vessels and cruise liners, as well as physical damage to corals from groundings of ferries and tourist boats.

If, in addition to these direct threats, the global impacts of climate change, ocean warming and ocean acidification are taken into account, experts now consider 75 per cent of all tropical coral reefs to be endangered. Ocean warming is of particular concern. Corals are dependent on symbiotic single-celled organisms living on their surface



2.21 > An international team of scientists defined four categories of threats from local sources that affect tropical coral reefs. If these threats are integrated it becomes apparent that 60 per cent of reefs are at least under medium threat. When local threats are combined with thermal stress from ocean warming, this figure is as high as 75 per cent. The single most significant threats are overfishing and destructive fishing, with 55 per cent of the world's tropical reefs under at least medium threat from these factors. Individual local threats were classified as low, medium, or high. Reefs with multiple high individual threat scores may reach the very high threat category in the summary assessment.

Tropics
The tropics are a climate zone limited in latitude by the Tropic of Cancer in the northern hemisphere and the Tropic of Capricorn in the southern hemisphere. In some regions, corals may also occur outside of the tropical zone up to approximately 30 degrees of latitude, for example off Florida or in the Red Sea. For simplicity such corals are also referred to as tropical. Cold-water corals also exist; these are adapted to cold water, greater depths and lower light levels. Such corals occur off Norway, for instance. Map 2.22 does not take cold-water corals into account.



2.22 > Tropical corals occur in a zone extending from roughly 30 degrees North to 30 degrees South of the equator. In order to assess the threat status of the world's coral reefs, scientists have compared the major coral reef regions.

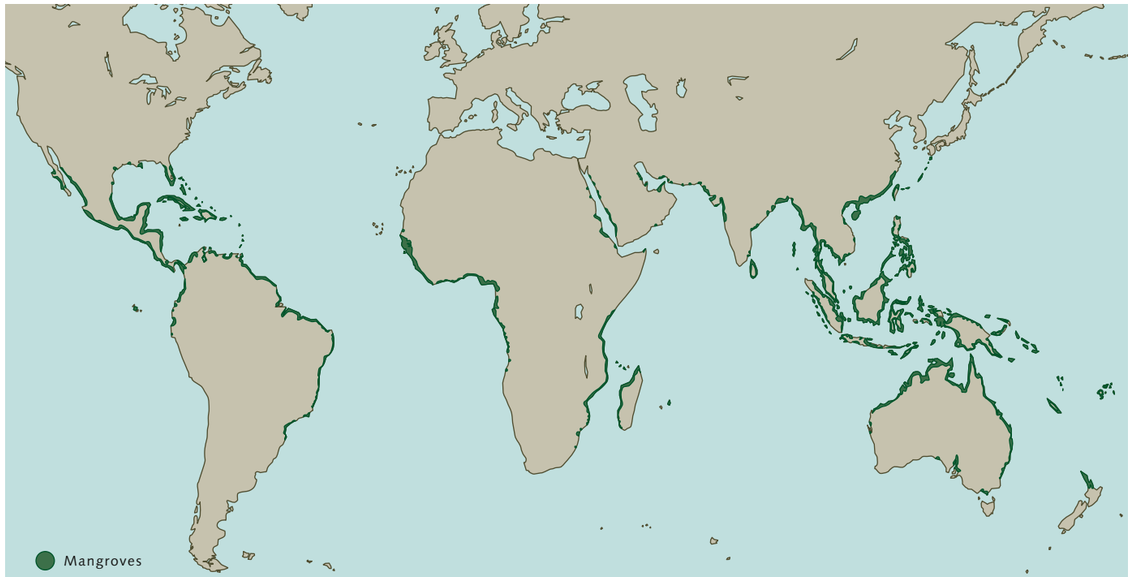
which photosynthesize and provide nutrients that nourish the corals. If the water becomes too warm, the symbionts die first, followed by the corals. Ocean acidification is an additional stressor for corals.

At the global level, the most highly endangered coral reefs are those in South East Asia, where 95 per cent of all reefs are under pressure from at least one of the individual local threats and approximately 50 per cent are facing multiple threats. Coral reefs in Indonesia and the Philippines are particularly affected. Overfishing and destructive fishing practices are the greatest stressors in those two regions.

Among the coastal habitats which are highly endangered worldwide, mangrove forests are one of the most im-portant. Mangrove trees are the only tree species that can grow directly in seawater. Their roots are either permanently submerged or anchored in damp sediment. Mangroves occur in the tropics and subtropics. Mangrove trees have developed metabolic processes allowing them to store and secrete salt taken up through their root system. Some 70 mangrove species have been documented worldwide. The highly branched submerged mangrove roots are an important habitat, supporting many species of fauna and, in particular, juvenile fish. As mangrove forests surround the coastline like a green belt, they also function as natural breakwaters and protect coasts from tsunamis and storms.

In recent years, mangroves have been destroyed in many places. Mangrove forests have often been drained and filled in to gain development land for harbours or hotels. In many regions, mangroves have also been destroyed for shrimp farm developments. Approximately 70 per cent of the mangrove forests of Ecuador and the Philippines were destroyed for shrimp farming.

An additional factor contributing to the destruction of mangrove forests is timber harvesting, which threatens the livelihoods of the often poor coastal populations. The loss of mangroves entails the loss of fish nursery grounds. In many areas where mangrove forests have been destroyed, fishermen are already landing significantly less fish. And where the mangroves' coastal protection function has been lost, storms now cause significantly more damage than they did only a few years ago.



2.23 > Mangroves occur in the tropics and subtropics. There are a total of 70 species of mangroves, many of which are at risk of extinction, especially species in Indonesia, the Philippines and Central America.

Overfishing

Approximately 90 per cent of the world's wild-caught fish comes from coastal regions or exclusive economic zones (EEZ) where fishing rights solely fall to the relevant coastal state. Many nations have overexploited fish stocks in their coastal waters and EEZs in recent decades. As a result, some fish stocks have seen a drastic decline. According to the Food and Agriculture Organization of the United Nations (FAO) the proportion of collapsed or overfished stocks increased from 10 per cent in 1974 to 28.8 per cent in 2011. As initially many of the northern hemisphere fish stocks had been fished out, commercial fishing moved ever further south from the traditional fishing grounds in the North Atlantic and North Pacific. This situation poses difficulties on two counts: Firstly, in some regions overexploitation undermines the livelihoods of local fishermen and deprives the local population of an important food source. This problem is known from Senegal, for instance. The Senegalese government, which has since been voted out of office, sold fishing licences to foreign-owned fishing fleets. These fleets fished the waters off the Senegal coast so intensively that the local fishers' catches have declined massively. Secondly, intensive fishing has the capacity to alter marine food webs and in turn whole ecosystems. In the early 1990s, industrial fishing led to the collapse of the cod stocks off Nova Scotia on Canada's east coast. Despite a moratorium on cod fishing, stocks have not really recovered to date. It is thought that the species' ecosystem has been perturbed to such an extent that cod recruitment is very low. Cod is a predatory fish preying on smaller, plankton-feeding species such as herring or capelin. As the cod stocks collapsed, the small plankton-feeders erupted, competing with the similarly plankton-feeding cod larvae for food sources. Moreover, predation of egg and larval stages of cod by both herring and capelin further decimated the offspring. As a result, cod stocks show little sign of recovery to date.

Changes in biodiversity

Overfishing and eutrophication as well as thermal stress and acidification impact on coastal biodiversity and habitats. In some cases there are synergistic interactions bet-

ween these factors. In other cases even just one factor strongly alters the marine environment. Eutrophication for example can affect larger species of algae that are anchored to the seabed. Increased plankton growth makes the water more turbid and reduces the amount of light reaching deeper areas. Bladder wrack *Fucus vesiculosus*, for example, which anchors itself to rocks on the seafloor, has disappeared from depths of 6 to 12 metres in the Baltic Sea owing to this lack of light. It now only occurs in shallow waters with sufficient light levels. Tragically the loss of bladder wrack stands also entails the loss of habitat of juvenile fish as well as numerous other organisms living on these algae.

Coastal habitats also change in response to invasive alien plant and animal species, a phenomenon termed "bioinvasion" by scientists. There are generally three pathways for the introduction of non-indigenous species from one of the world's coastal regions to another, each of which is responsible for about one third of marine bioinvasions:

- Introduction as a result of the settlement of organisms on hulls of commercial vessels (biofouling). In particular, such organisms include bivalves, molluscs and barnacles all of which directly attach themselves to the vessels' sides. A large number of other species find shelter amongst the biofouling.
- Introduction with ships' ballast water. Ballast water stabilizes cargo ships travelling empty of cargo. Ships take on and discharge ballast water as they load and unload cargo. Eggs and larvae of marine species may be transferred with the ballast water, as can pathogens.
- Introduction by mussel farmers or the aquarium trade. Mussel seed-stock, such as is set in oyster farms for example, spread in the areas of introduction. Other species are often attached to the seed mussels and under favourable environmental conditions these may also take hold in the new region. Owners of aquaria occasionally engage in the deliberate release of fish and other species simply to dispose of them.

2.24 > The red lionfish *Pterois volitans* is native to Japanese waters. This predatory species has invaded Atlantic waters from Florida to the Caribbean. It is thought that the first individuals were released off the U.S. Atlantic coast in the early 1990s by aquarium owners.

The red lionfish *Pterois volitans* is an example of how strongly a non-native species can assert itself in new areas. The red lionfish is native to Japanese waters but has invaded Atlantic waters off Florida, the Gulf of Mexico, and Caribbean coral reefs. It is a predatory fish which decimates native species of fauna. It possesses venomous spines that are a strong deterrent to predators. The most likely avenue of introduction of this species off the U.S. Atlantic coast is its release in the early 1990s by aquarium owners. Since then the species has extended its range far to the south.

The spread in Argentina of the invasive golden mussel *Limnoperna fortunei*, which is native to estuaries in China, has had major economic repercussions. In the Río de la Plata basin, golden mussels displaced native species and they continue to proliferate on harbour walls and clog pipes carrying drinking water or cooling water as well as hydropower plant turbines. At great expense, they must regularly be removed from such structures with the aid of pressure washers.

It is now known that bioinvasions affect in particular harbours in the subtropics and tropics. Biomathematicians recently calculated the risk of new primary invasions between individual ports through the transfer of ballast water. To this end they analysed the logs for the years 2007 and 2008 from more than 30 000 ships, mapping each individual stop in about 1500 harbours. The scientists combined the network of global cargo ship movements with data on water temperatures and salinity in the ports. Their findings suggest that the ports and regions at greatest risk are Singapore, Hong Kong, the Panama and Suez canals, and Kaohsiung in Taiwan.

Changes in sediment transport

Just how intimately the coast and its hinterland are connected is evident from changes in sediment transport from rivers into the sea. Sediments are often deposited at the mouths of rivers, such as in deltas, where thick sediment packets may accumulate. As a result of this accumulation of sediments the lithosphere, the earth's uppermost layer, slowly sinks. This process can have different consequences depending on the local situation. The slow increase in the thickness of sediment may compensate for the sinking lithosphere. Another possibility is that sediment transport is so strong that the sediment layer slowly grows upwards, thereby creating an ever-widening delta system as the river continuously seeks new pathways to the sea. Yet another possibility is that the sediment supply is insufficient to compensate for the sinking lithosphere, resulting in the delta region slowly subsiding and the sea level rising in relation to the land surface.

Delta subsidence can also result from the construction of dams. As the water is held back, sediment supply becomes insufficient. Worldwide more than 41 000 large dams are in operation. There are also many smaller dams and reservoirs. Together, they block 14 per cent of the total global river flow and trap enormous amounts of sediment. These trapped sediments are then not available to replenish coastal sediments, which are continuously being lost to currents and wave action, and to avoid subsidence.

The Nile is a good example of this. Before construction of the Aswan Dam, recurrent annual floods washed fertile sediments from the interior of the continent into the Nile Delta on the Mediterranean Sea. Not only were the sediments essential for the farmers on the banks of the Nile, they were also crucial to compensating for subsidence in the heavy delta region. After the dam was built in the 1960s, the flooding and delivery of sediment came to a halt. Subsidence in the Nile Delta continues to this day. Moreover, this has resulted in saltwater intrusion into the mouth of the river and subsequent groundwater salinization. These processes in turn led to sustained crop yield reductions and massive coastal erosion. Similar problems can be expected to arise in connection with the Three Gorges Dam in China's Yangtze Delta.

Humans have also impacted on sediment budgets in other ways. Deforestation, overgrazing and unfavourable arable systems give rise to severe **soil erosion**, especially in tropical regions. Rains wash elevated levels of soil into the rivers. The water then becomes turbid and water quality decreases. Increased sedimentation in the estuaries at the mouths of the rivers can smother and thus destroy estuarine sea floor habitats.

Coastal regions under threat from climate change

Many threats to coastal regions originate in the region in question or in the coastal state's hinterland. In contrast, climate change is a phenomenon that knows no borders and has a global impact. From the human perspective, sea-level rise in particular poses a threat. If efforts to limit carbon dioxide (CO_2) emissions from the burning of natural gas, oil and coal remain unsuccessful, global warming will lead to further melting of the Earth's ice masses. The melting of the relatively thin sea ice, which increases and decreases with the seasons in any case, is of lesser concern. Things will get critical however if the very thick ice sheets on land melt: the upland glaciers or the Greenland ice sheet. The latter covers an area of 1.8 million square kilometres, roughly 80 per cent of the surface of Greenland. Their melting would cause a significant worldwide rise in sea levels.

According to recent scientific projections, global sea-level rise to the end of this century will be in the order of 80 to 180 centimetres, unless CO_2 emissions are curbed. The scientists note this with grave concern, as many people live in shallow coastal regions today. The United Nations predict that between 50 and 200 million people may be displaced by 2050 due to flooding. Worldwide roughly 700 million people live in low lying coastal areas only a few metres above sea level, or, as for example in the Netherlands, even below sea level and protected by dikes.

It is as yet uncertain in how far climate change will alter ocean currents and, in turn, winds. Similarly, it is impossible to say whether more frequent and extreme storms will occur or where that might happen. A range of mathematical climate models have reached different conclusions in this respect. While all models employ the same equations, standards of measurement and input parameters, it is difficult to correctly assess small-scale climate impacts and to correctly transfer these into large-scale global models.

The quest for an ideal state

All in all the oceans are in a bad state now. They are over-exploited and polluted. Humankind has clearly failed to sustainably use the marine natural capital and to ensure that the oceans can continue to provide their ecosystem services in the long term. The issues have been known for a long time.

While frequently the political will for sustainable development has simply not existed, much too often in the past conservation objectives were set out that were much too vague to be translated into tangible political action. A number of countries as well as the European Union are currently working on defining unambiguous sustainability targets on which appropriate political decisions are to be based. For this to happen the scientific community must provide a detailed analysis of threats and problems, enabling the political level to set the correct course towards sustainable development.

This requires that, firstly, one must determine the present status of a habitat and assess in how far it is intact or damaged by human activity. Secondly, one must define an ideal status the habitat is intended to achieve as a result of conservation measures, in other words one must describe what a habitat is supposed to be like if it was sustainably used.

The problem is that many habitats are now in poor condition. The original state these marine regions were in decades or centuries ago is not always known. Moreover, it is considered unrealistic to strive for a pristine status, unimpaired by humankind, given that most of the world's regions have been affected and changed by human activity for centuries. Rather, it would be desirable to strive for an environmental status which, in the interest of sustainability, maintains natural capital in the long term.

Therefore, the political arena and the scientific community must first define a status which can serve as a guideline and is expressive of the desired outcome of sustainable development.

Global overview

For certain marine regions, such as the North Sea, environmental analyses have of course been conducted for many years. For example, the presence of certain pollutants has been measured. However, a comprehensive

The vicious cycle of poverty and environmental destruction

In many regions, the destruction of coastal ecosystems primarily harms the poor as they are dependent for their survival on a range of products obtained in their immediate surroundings, such as fish or mangrove timber. They do not earn enough money to be able to acquire food or energy by other means, or to move away from regions affected by environmental degradation. In this context, experts distinguish between two types of poverty: exogenous poverty and endogenous poverty.

Exogenous poverty in a population is initially caused by external factors. This may happen, for example, if resource exploitation ruins local livelihoods and the local population does not share in the proceeds, such as in cases where large fishing fleets, with the government's permission, exploit local fishers' fishing grounds. Similarly, the exploitation of mineral resources in a context of irresponsible governance may cause exogenous poverty. In Papua New Guinea, for example, millions of tonnes of toxic effluent were discharged from a copper and gold mine into the Ok Tedi river and the sea between 1984 and 2013, thus poisoning the river, swamps and coastal waters for many years.

Endogenous poverty as caused by the population itself often follows on from externally induced (exogenous) poverty. In order to survive, people may need to exploit alternative resources, for example by switching from fishing to arable cropping. Due to a shortage in agricultural land, unsuitable soils are often tilled or forests are cleared. Soils degrade and erode, resulting in further environmental degradation. More often than not endogenous poverty draws people into a vicious cycle as the progressive loss of natural resources results in further overexploitation of resources, i.e. the natural capital.

Haiti has suffered the drastic consequences of this vicious cycle. Haiti is a country on the island of Hispaniola in the Caribbean, occupying the western part of the island, while the eastern part is the territory of the Dominican Republic. Plagued by civil wars and many years of irresponsible government policies, Haiti is one of the western hemisphere's poorest countries. Roughly 65 per cent of Haiti's inhabitants live on less than 1 US dollar a day. The World Bank defines extreme poverty as having to subsist on less than 1.25 US dollars/day.

Haiti used to be completely forested. However, as early as the 1950s widescale logging commenced for the production of wood charcoal. Rapid population growth and poverty led to the almost complete deforestation of Haiti by the 1990s to make way for cropland. Forest cover declined to roughly 4 per cent of the original area. Coastal mangrove forests were also largely destroyed. Haiti's climate today is much drier than it was in the past, as the soils retain and evaporate much less water than they did when they still had their forest cover. Precipitation has declined by up to 40 per cent.

The fallout of this poverty-induced deforestation proved no less than catastrophic when in 2004 Hurricane Jeanne swept over Hispaniola and dropped torrential rainfall, flooding parts of the island. The destructive power of Hurricane Jeanne reigned free in the unprotected Haiti. Due to the lack of forest cover many regions suffered landslides. Approximately 5400 people were killed. In contrast, only 20 people died in the Dominican Republic which has retained roughly 28 per cent forest cover and is still to some extent protected by mangrove forests.

2.25 > Image of the border, formed by a river, between Haiti (left) and the Dominican Republic. Poverty has resulted in the almost complete deforestation of Haiti. In contrast, the Dominican Republic retained a greater proportion of its forest cover, offering the country's population better protection from the effects of hurricanes.

worldwide analysis of the status of all oceans had long been missing. Eventually this was delivered by a working group comprising more than 65 U.S. scientists who published the Ocean Health Index (OHI). The Index initially evaluated the status of exclusive economic zones (EEZs) adjacent to 171 countries.

To establish the Ocean Health Index, the scientists articulated ten generally accepted categories that are reflective of the oceans' sustainable ecological, economic and social significance for humankind. These are closely related to the ecosystem services categories used in the United Nations Millennium Ecosystem Assessment (MA) and include, for example, coastal protection, biodiversity, tourism and recreation, and the ocean's carbon storage function. The fact that the sea provides humans with valuable species of flora and fauna, or special places, is also given consideration.

The scientists compiled information and comparable data with reference to the individual categories from both national statistics and international surveys. For the assessment of fish stocks the Ocean Health Index draws for example on FAO (Food and Agriculture Organization of the United Nations) data. The Index assigns a score for each of the categories, framed as goals. Each goal scores from 0 (very poor) to 100 (very good). This evaluation allows both for a ranking of the various marine regions as well as for an overall global assessment of ocean health.

The OHI results showed that the most remote, sparsely settled or little-used marine regions are the most healthy. The highest score for example was reached by the Heard and McDonald Islands, a nature reserve in the southern Indian Ocean and part of the Australian territory. In contrast, the situation is worst in seas near war-torn developing countries, such as in the marine region off the West African country of Liberia.

Strengths and weaknesses of the global analysis

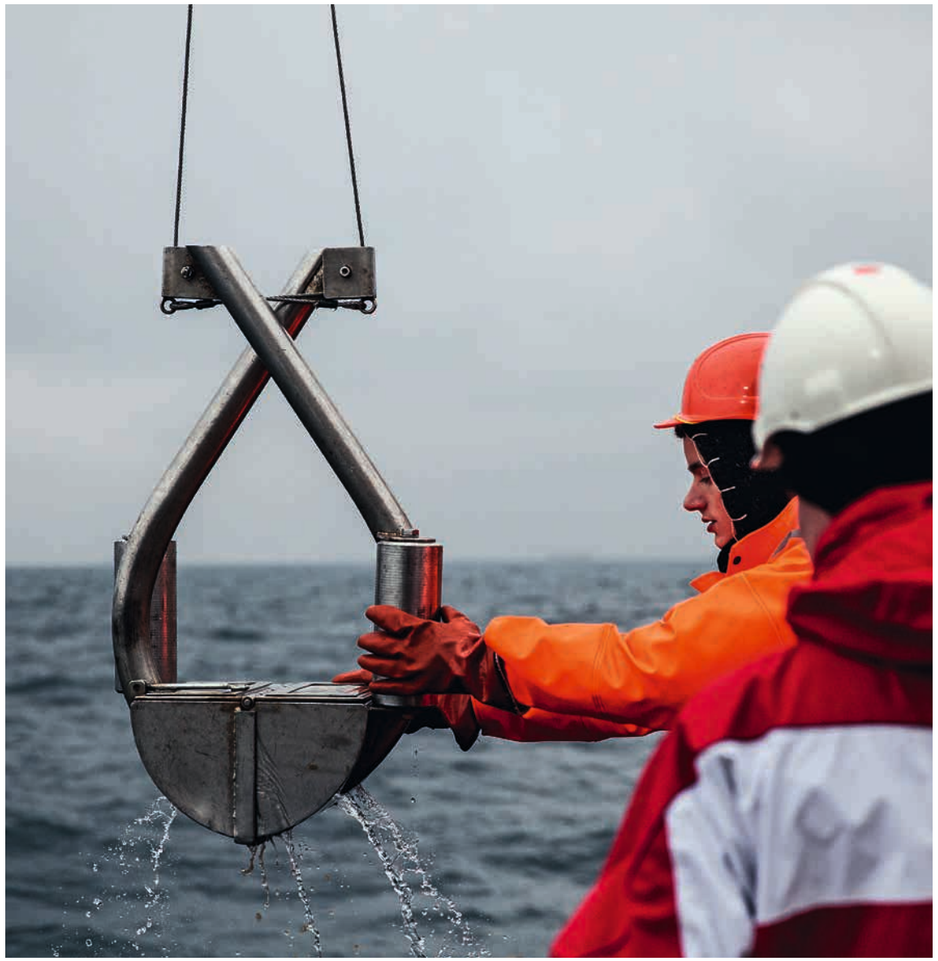
The OHI is definitely considered a welcome tool that provides individual countries with an assessment of the health of their waters. Ideally the Index will inform policies based on the concept of sustainability. However, one of the difficulties in compiling a comprehensive index is the fact that errors or ambiguities may arise when such a vast amount of data is collated and processed, and thus the index may not correctly reflect reality. Another criticism levelled at the OHI concerns the fact that simple arithmetic averages of the scores for the ten categories were calculated for the Index. Critics argue that a good score in one category can compensate for a bad score in another. For example, if a particular marine region achieves a high score of 90 points for the coastal population's economic situation but only scores ten points for water quality, the average score is 50. At the same time, a region scoring 50 points for both goals is given the same overall score. The scoring system does not elucidate the actual differences between the two regions. Yet another criticism is that the OHI assessment method is implicitly based on the concept of weak sustainability which basically allows for unlimited substitution between depleted natural capital and other natural capital. Critics therefore call for different weightings to be applied to the categories in the calculation of index scores.

Every year since its publication in 2012 the OHI has been improved and updated. The OHI no longer just covers Exclusive Economic Zones but now also includes the Arctic and Antarctica along with the High Seas. By 2014, 220 Exclusive Economic Zones were being assessed and a further 20 ocean sectors had been added to the Index. All data are published and freely accessible at the OHI website. The current global Ocean Health Index score is 67.

Concrete values for a policy of sustainability

While individual marine health index scores allow for comparisons between regions or for year-on-year comparisons of the global situation, concrete political measures call for parameters and limit values that are useful for practical application.

Efforts are currently being undertaken in Europe to define such values. These efforts are underpinned by the European Marine Strategy Framework Directive (MSFD) which came into force in 2008. The Directive's objective is to afford better protection to the marine environment than in the past and allow already damaged marine regions to recover. The overarching goal of the Directive is to achieve "Good Environmental Status" (GES) by 2020 across Europe's marine environment. To this end the MSFD follows an ecosystem-based approach, which considers and protects entire ecosystems rather than just individual species. Moreover, the MSFD takes account of the concept of intergenerational responsibility, a responsibility to be assumed by the current generation. The Directive defines "good environmental status" as follows: "'Good environmental status' means the environmental status of marine waters where these provide ecologically diverse and dynamic oceans and seas which are clean, healthy and productive within their intrinsic conditions, and the use of the marine environment is at a level that is sustainable, thus safeguarding the potential for uses and activities by current and future generations."



2.26 > On a research expedition in the Baltic Sea German scientists lift a marine bottom sampler on board containing a sediment sample. They are looking for certain species and want to find out in which of the Baltic's sediments these species occur.

Descriptors of good marine environmental status

The environmental status of EU marine waters is assessed on the basis of eleven qualitative descriptors of good environmental status. Each of the descriptors is accompanied by a number of related criteria and indicators, i.e. by tangible parameters that can be measured and compared. This principle can be elucidated using the example of Descriptor 10 on "Marine litter". Generally the EU Member States need to consider all of the descriptors and identify those that are appropriate to describing good environmental status in their marine waters. Descriptors 1, 3, 4 and 6 describe the state of marine ecosystems and the species they host while the remaining descriptors cover pressures on the marine environment.

1: Biological diversity
2: Non-indigenous species
3: Populations of commercially exploited fish and shellfish
4: Food webs
5: Eutrophication
6: Sea floor
7: Hydrographical conditions
8: Contaminants
9: Contaminants in food
10: Marine litter
11: Introduction of energy

Descriptor 10:
"Properties and quantities of marine litter do not cause harm to the coastal and marine environment."

Criterion 1: Characteristics of litter in the marine and coastal environment

Indicator 1: Trends in the amount of litter washed ashore and/or deposited on coastlines (litter concentration). The analysis includes litter composition, spatial distribution and litter source. Under the OSPAR Convention (Oslo-Paris Convention of 22 September 1992), marine litter collections are carried out to this end on Northeast Atlantic coasts and the litter is recorded under standardized categories.

Indicator 2: Trends in the amount of litter deposited on the sea floor, floating in the water column or floating at the surface. The analysis includes litter composition, spatial distribution and litter source. Amongst other techniques, survey flights are used to establish such trends.

Indicator 3: Trends in the amount, distribution and composition of microparticles (in particular plastics).

Criterion 2: Impacts of litter on marine life

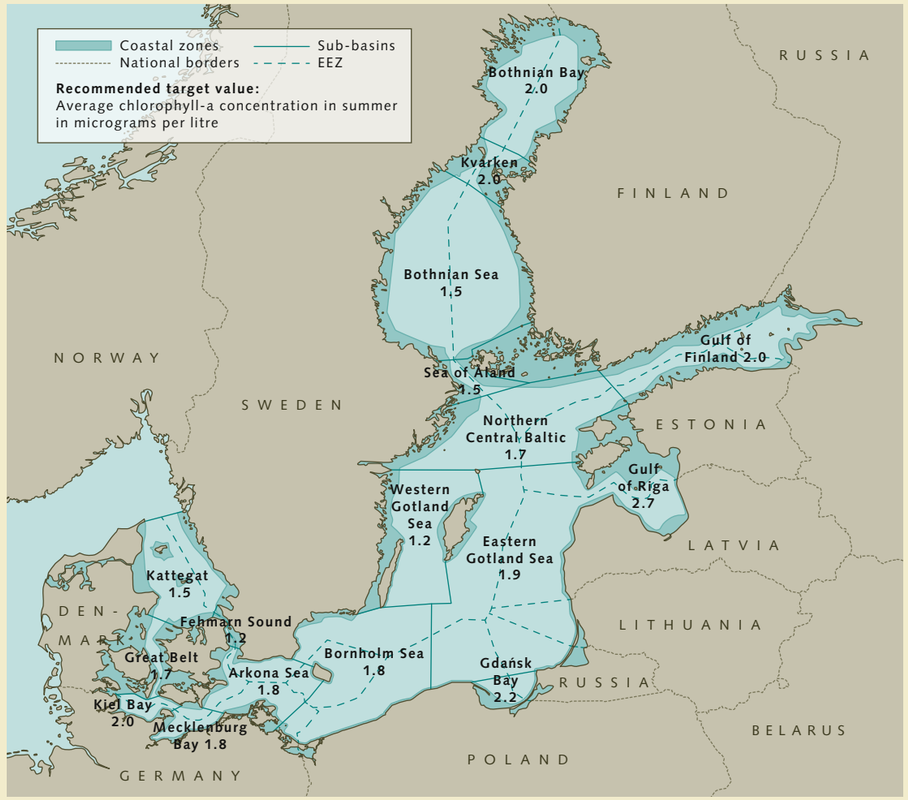
Indicator 1: Trends in the amount and composition of litter ingested by marine animals (stomach analysis). To this end, dead or stranded birds found on Northeast Atlantic coasts are examined, such as fulmars (pelagic seabirds). Dead harbour seals, dolphins, porpoises and grey seals are also analysed.

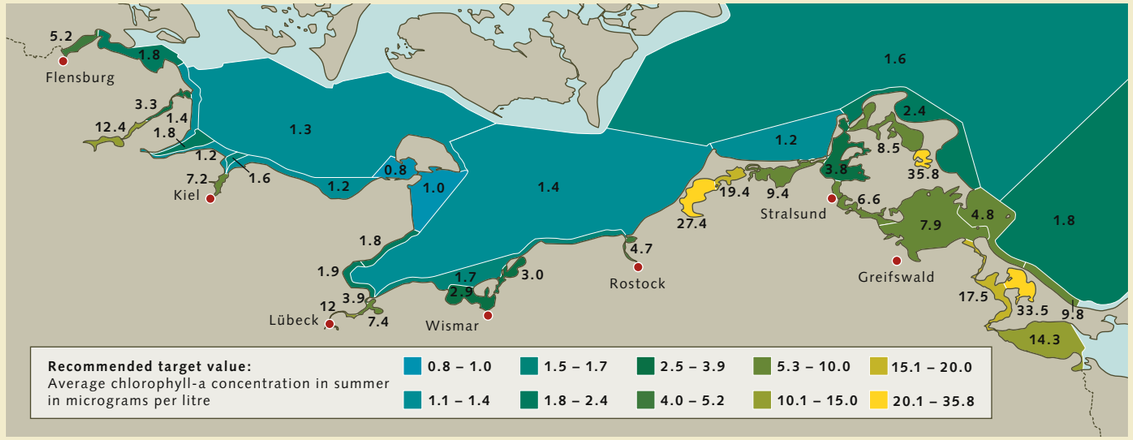
The MSFD sets out that the evaluation and monitoring of marine waters is to be based on 11 descriptors and roughly 100 criteria and indicators. The descriptors are categories of relevance to the marine environment, such as the descriptor "eutrophication". Each descriptor is associated with several tangible criteria. The criteria in turn are described by directly measurable indicators, which serve as limit values. One of the criteria associated with the "Eutrophication" descriptor is "Direct effects of nutrient enrichment" to which the indicators "Chlorophyll concentration in the water column" and "Water transparency" are assigned. Chlorophyll concentration is a measure of the amount of phytoplankton, which, just like terrestrial plants, contains chlorophyll. The more nutrients are contained in the water, the greater the amount of algal biomass and the higher the chlorophyll concentration, the measurement of which in a lab is quite straightforward.

However, to set appropriate individual limit values remains a major challenge. For example, to answer the question as to the maximum quantity of nitrogen a river may discharge into coastal waters, scientists must first determine the amount of nutrients a coastal region may buffer without suffering deterioration. A current corresponding research project on the German Baltic Sea coast shows just how difficult this is.

Guide values for the Baltic Sea have been in existence for some time. They are published by HELCOM, an intergovernmental marine environment protection commission established in the context of the Helsinki Convention by the countries bordering the Baltic. The Commission divided the Baltic Sea into 17, in part very divergent, marine regions ("sub-basins"). They range from the Kattegat which is influenced by North Sea water to the Gulf of Bothnia which freezes over in winter. HELCOM takes account of these differences by setting individual values for maximum allowable nitrogen inputs in each of the sub-basins, i.e. the maximum quantities of nitrogen a given sub-basin can take up without ill-effect.

However, a German research project has demonstrated that this division does not give sufficient consideration to natural differences between the various coastal waters. HELCOM does not take account of the fact that





2.27 > To reduce eutrophication in the Baltic, HELCOM, an intergovernmental marine protection commission, has divided the Baltic Sea into sub-regions, each of which was assigned an individual maximum allowable level of nitrogen inputs (left). German scientists criticized that these maximum allowable inputs do not consider small-scale variations in natural nutrient concentrations between various types of coastal waters such as inlets (bodden) or fjords. To address this issue they calculated small-scale, spatially differentiated thresholds for nutrient inputs (bottom). The figures above show recommended thresholds for the summer period. The figures do not reference maximum nitrogen loads but maximum levels in chlorophyll values, i.e. thresholds for algal concentrations which in turn are influenced by nutrient loads.

when it comes to natural nutrient concentrations, there can be variations between individual Baltic coastal waters on very small spatial scales.

Given that bays, inlets (bodden) and fjords are closely connected to the land, nutrient concentrations are much higher in such waters, even in the absence of mineral fertilizer inputs, than for example in coastal segments without any bays or riverine tributaries. Therefore the threshold values as set by HELCOM proved unrealistically strict in many areas. The researchers concluded that it would be impossible to meet such low thresholds even under conditions of massive reductions in riverine nitrogen inputs. The HELCOM values therefore proved unsuitable for German Baltic waters.

The research project mentioned above has now succeeded in defining spatially differentiated thresholds which take more subtle differences between various Baltic water bodies into account and prescribe different levels of maximum allowable nitrogen inputs with reference to the individual local situation. This allows for the preparation and implementation of targeted pollution control measures in Baltic rivers.

Guidance from the nineteenth century

The MSFD proposes that the definition of what constitutes good environmental condition and the establishment of threshold values take their guidance from the situation that prevailed in the second half of the nineteenth century. At that time, European coasts had already been impacted by human activity, by harbours and other infrastructure, and waters were less polluted, especially owing to the fact that mineral fertilizers had not yet come into use in the farming sector. Inputs of wastewater and excrement were relatively low as they were limited to discharge from a small number of coastal villages and towns. Scientists are facing a problem however, given that historic data on nutrient inputs are scarce; unlike today environmental parameters were not systematically and centrally recorded.

Baltic researchers therefore turn to mathematical modelling to approximate, as much as possible, past conditions. Due to the lack of historical data they are using proxy data.

Scientists engaged in the Baltic Sea project used historical sources on land use which contain details of the extent and location of arable lands. Past crop production methods as well as the amounts of manure that were customarily applied in the past are known. Appropriate models can therefore be used to estimate past nutrient loads in rivers and coastal waters. The model shows that nutrient loads have roughly increased fourfold since then. The application of historic nutrient loads to the model demonstrates that nutrient concentrations in the Baltic were much lower than they are today, with significant regional variations in the ratios between past and present concentrations.

The nutrient concentrations calculated by the model can not however be directly framed as target values for the present. Firstly, too little is known as to how changes have impacted on the Baltic ecosystems in terms of plankton species composition or benthic macroalgae, which means there are discrepancies between the current situation and that of the past. Secondly, nutrient inputs as low as in the reference period can not be achieved, not even in the long term, since soils have received nutrient inputs for more than 150 years. As a result of their nutrient history, today's soils are of a different character than those of the past. Even if nutrient inputs to soils were halted today, an unrealistic proposition with a view to food production, the soils would continue to discharge elevated levels of nutrients for a long time to come. It is for these reasons that the newly calculated target values are not simply based on the lower historical values. Instead, higher target values were derived which take current measured water quality into account.

This example demonstrates just how onerous it can be, and how controversial, to define reliable indicators and determine what constitutes "good environmental status". Generally only wealthy industrial nations and newly industrialized countries have the financial means at hand to tackle this kind of work. The countries which scored the lowest on the Ocean Health Index have neither the funds nor the expertise to carry out comparable studies.

Conclusion

Marine ecosystem services at risk

The sea is of fundamental importance to humankind due to the many ecosystem services it provides. To gain a clearer analytical framework for the vast array of these services, marine experts have divided them into four classes. The defined categories are: provisioning services, supporting services, regulating services and cultural services.

Provisioning services include, in particular, the production of marine fish for human consumption. Cultural services comprise, amongst others, tourism and traditions connected to the sea, such as artisan boat-building. Supporting services include first and foremost primary productivity, i.e. the generation of biomass by phytoplankton by means of photosynthesis. Finally, regulating services are taken by scientists to include fundamental biological, chemical and physical processes in the oceans, such as nitrogen and carbon cycles as well ocean currents which affect the terrestrial climate amongst other things. The elimination of marine pollutants is another regulating service offered by marine ecosystems.

Many of these services are now under threat from human overexploitation, environmental pollution or greenhouse gas emissions. Carbon dioxide emissions in particular pose a global threat to the oceans today. Firstly, these emissions are causing the oceans to warm as a result of the greenhouse effect. Secondly, a significant proportion of atmospheric carbon dioxide becomes dissolved in seawater, slowly acidifying the oceans.

Coastal regions, many of which are extremely densely settled, are under particular pressure from environmental problems. The United Nations estimate that today more than 40 per cent of the world's population, i.e. more than 2.8 billion people, live within 100 kilometres of the coast. Thirteen of the world's 20 megacities home to 10 million or more people lie along coasts. Many coastal regions are subject to intense land use, and in turn also to intense degradation.

Eutrophication of coastal seas due to nutrients from agricultural sources is a major problem. It results in strong algal growth, and as the algae decay oxygen depletion in the water ensues. The direct destruction of inshore habitats also continues to this day, affecting wetlands, saltmarshes and mudflats, coral reefs and mangrove forests. They mostly fall victim to construction projects, coastal impounding and pollutant discharge.

In order to establish a pathway towards sustainable use of marine ecosystems, scientists are now attempting to determine firstly the state of these ecosystems. To take well-targeted improvement action, it is essential to have detailed knowledge of the degree to which an ecosystem has been impaired or in how far its status still resembles the original "good status".

To this end, U.S. scientists have developed the global Ocean Health Index which allows for comparisons of the status of different marine ecosystems. The Index captures environmental aspects such as species diversity, while also extending to social aspects such as the status of coastal economies.

But this is not sufficient for targeted environmental policy measures. Concrete measurements and limit values are needed to ensure sufficient reductions in nutrient inputs. In Europe, environmental indicators and targeted values are currently being defined as part of the Marine Strategy Framework Directive. The aim of the Directive is to once again achieve a good environmental status across Europe's marine environment. To this end, all pressure indicators are assigned clear limit values which serve to provide political direction.

3 Politics and the oceans

> The oceans can only be protected if all stakeholder groups pull together. Good governance of the oceans therefore calls for participation from the local people directly affected and from the economic and policy spheres. National and international agreements are in place, enshrining comprehensive marine protection in law. However, the rules laid down need to be respected in practice.

On the difficulty of governing the sea

> Worldwide there are dozens of different institutions dealing with the use or protection of the sea. These include multinational organizations like the United Nations and, of course, national governments themselves. The fragmentation of responsibilities makes it harder to ensure that use of the sea is entirely sustainable. Experts are therefore trying to define universally applicable rules for good governance of the sea.

Lack of common purpose

The sea and its ecosystem services are a common resource. Unlike privately owned properties on land, for example, they do not belong to individuals but are available to the whole community.

Many of the resources in the sea are finite, fish stocks being one example. If individual nations or companies help themselves to the sea's resources as they see fit, sooner or later these resources will be exhausted. Today many fish populations are already classified as overfished due to excessive catches over the years. Economists use the term "commons" to talk about publicly available resources (like the fish in the sea) which are freely usable but limited in supply. Originally the concept referred to land areas such as fields or pastures used collectively by the citizens of a community.

The problem with the use of commons has always been that those interested in using this kind of resource find themselves competing with each other. If one company or country makes use of a common resource, less of it is available for the other stakeholders. From a purely economic viewpoint, it is worthwhile for a company or country to exploit these resources to the fullest possible extent in order to secure the maximum possible share and generate profits accordingly.

In past decades this approach has led to ever more serious harm to the marine environment. Unrestrained fishery is one of the uses of the commons that will tend to cause such harm. Likewise, the discharge of pollutants from industry or from municipalities into the sea is another example of a use of marine commons that is ultimately selfish. Individual companies, municipalities or countries save themselves large expenditures for the disposal of pollutants by making use of coastal waters as a free drainage tank for effluents. For the protection of commons to make sense, on the other hand, many users or states need to cooperate.

An example that clearly underscores this dilemma is fishing on the high seas, in international waters. Here the prevailing principle is that of freedom of the sea, according to which all nations can fish at will. It would be futile if one country alone refrained from fishing in order to protect overfished populations while other countries continued to fish excessively. It follows that comprehensive protection of the sea will only be possible in future if all nations will pull together with a common purpose.

Ocean governance – a nebulous concept

Marine protection is a matter that concerns everyone. But the question remains, how can use of the sea be regulated and governed to ensure that it is in fact sustainable? In this context researchers often speak of "governance". Much like the term "sustainability", no standard defini-tion of the expression "ocean governance" currently exists.

The Club of Rome, an international non-governmental organization (NGO) and expert panel founded in 1968, which deals with the negative consequences of economic growth, attempted to come up with a universal definition of the term. Accordingly, "ocean governance" was framed as the "the means by which ocean affairs are governed by governments, local communities, industries, non-governmental organizations, other stakeholders, through national and international laws, policies, customs, traditions, culture, and related institutions and processes."

3.1 > A factory ship where fish are processed on board. Whether this large-scale industrial form of fishery contributes to the decline of a fish population depends on the condition of that population to begin with.

Thinking in zones

This ideal of global sustainable ocean governance has not been achieved so far, for several reasons. One reason is the subdivision of the ocean into various zones, each of which is the responsibility of different institutions. According to the Convention on the Law of the Sea (UNCLOS), which was passed in 1982 by the United Nations Conference on the Law of the Sea as a kind of global constitution of the oceans and entered into force in 1994, today the following zones of the ocean are differentiated:

TERRITORIAL SEA: The territorial sea is the 12-nautical-mile zone. It belongs to a state's sovereign territory, and the right of peaceful passage prevails for international shipping. The other activities in this zone are subject to the legislation of the specific states. Legislation must be in line with internationally agreed rules provided that the state has ratified UNCLOS.

EXCLUSIVE ECONOMIC ZONE (EEZ): This extends from the outer edge of the territorial sea to a distance of 200 nautical miles (approximately 370 kilometres) offshore. Therefore the EEZ is also called the 200-nautical-mile zone. Included within the EEZ are the sea floor and the water column. Unlike the territorial sea, the EEZ is not part of a state's sovereign territory. Nevertheless, in its own EEZ only the coastal state may extract resources such as petroleum and natural gas, mineral resources and, of course, fish stocks. Other nations may only use the resources if the coastal state consents. Resource extraction in the EEZ is subject to the coastal state's legislation, which in turn must be in line with the international rules laid out in UNCLOS.

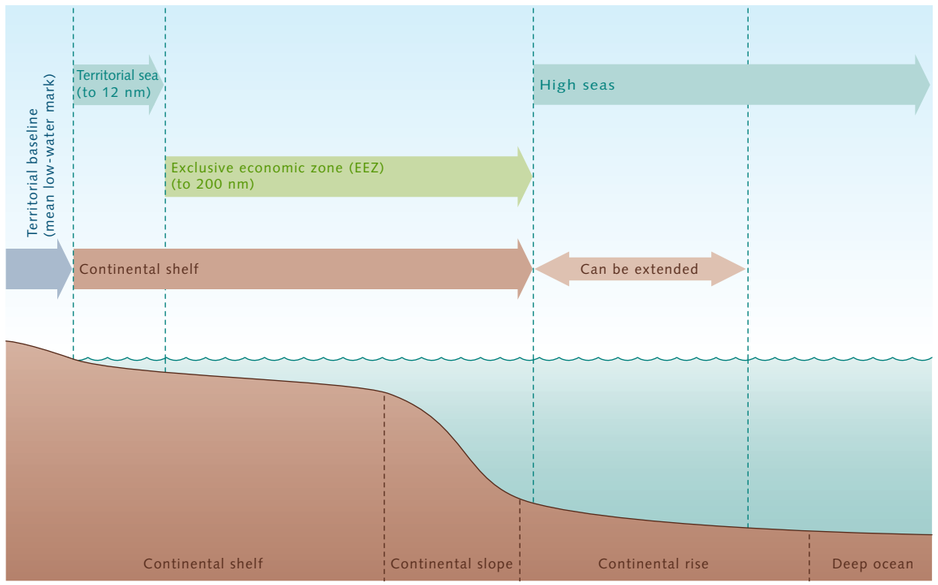
CONTINENTAL SHELF: The continental shelf is the gently or steeply sloping sea floor off the coast, which is a natural geological extension of the mainland. In the case of such a geological formation the country can exploit the sea

floor and its mineral resources up to a maximum of 350 nautical miles off the coast. In other words, it can extend its continental shelf rights.

HIGH SEAS: Adjoining the 200 nautical mile zone are the high seas, which no national state may claim for itself alone; they are available for use by all countries. Nevertheless, the use of resources in sizeable areas of the high seas is regulated. Fisheries, for instance, are regulated by one of the Regional Fisheries Management Organizations (RFMO) and its member countries, which specify maximum catch sizes for fish species. For the use and distribution of raw materials on the sea floor, in contrast, only the International Seabed Authority (ISA) is responsible.

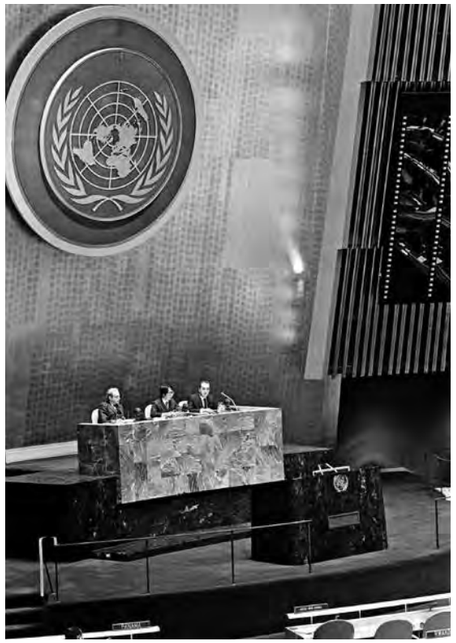
This zoning is fundamentally in conflict with any comprehensive sustainable ocean governance. Fish stocks can move across vast areas; toxic substances travel across national borders with sea currents and far beyond the bounds of an EEZ. And finally, as a consequence of climate change and particularly ocean acidification and sea-temperature rise, threats exist today which affect all marine areas equally, across all zones and borders.

Article 192 of the Convention on the Law of the Sea obliges all states parties to protect and conserve the marine environment. In addition, Article 192 ff. cites a list of obligations, setting out how states are to make use of resources in a sustainable and environmentally benign way and minimize marine pollution. Nevertheless, UNCLOS does not provide any unequivocal definition of sustainability or concrete environmental protection standards. It neither describes in detail how resources are to be used, nor can it determine, for example, catch quotas for fishery. The specifics of environmental protection are left to the individual states parties. This being the case, today it is commonplace for certain coastal states to neglect marine protection due to lack of political interest or lack of financial resources. A consistent global level of protection for the ocean has not been achieved to date.



3.2 > The United Nations Convention on the Law of the Sea (UNCLOS) partitions the ocean into different legal zones. Within this framework, the sovereignty of a state diminishes as distance from the coast increases. Adjacent to the inner waters is the territorial sea, which is also known as the 12-nautical-mile zone. Here the coastal state's sovereignty is already curtailed, because ships from all countries are allowed passage through these waters. In the exclusive economic zone (EEZ) which extends up to 200 nautical miles from the coast, a coastal state has the sole right to explore and harvest living and non-living resources. It is thus permitted to exploit petroleum and natural gas, mineral resources or fish stocks. In the continental shelf zone, which is a natural extension of the mainland and can extend beyond the exclusive economic zone, it may explore and harvest resources on the sea floor. Adjacent to the exclusive economic zone is the area of the high seas.

Much the same applies to fishery in the international waters of the high seas. According to the standards set out in UNCLOS, fishery is regulated in most international marine zones by one of the RFMOs. Usually it is the coastal states of a sea region that are organized in these RFMOs, along with just a few larger fishery nations. For example, the members of the RFMO responsible for the Northeast Atlantic, the North East Atlantic Fisheries Commission (NEAFC), include the European Union, Iceland, Norway and the Russian Federation. Other nations which do not belong to the RFMO responsible for the given sea area are not actually allowed to fish in that area. Nevertheless, illegal fishing could be taking place in these areas almost undetected, since such misconduct is rarely sanctioned. Irrespective of all the regulation of fishery, this means that even fish stocks in RFMO areas can be overfished.



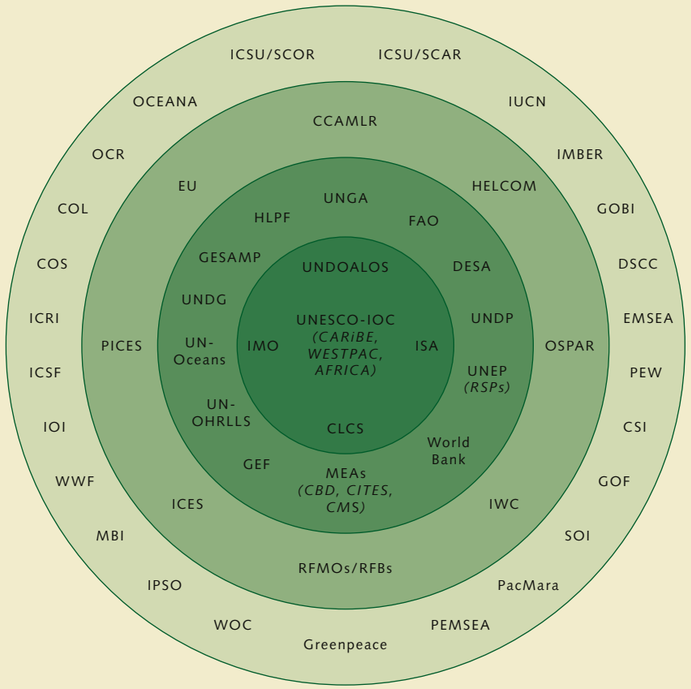
3.3 > A conference on the Convention on the Law of the Sea (UNCLOS), held in March 1982 at the United Nations in New York. UNCLOS is one of the largest legal regimes on ocean governance.

Too many institutions involved

A further reason why no comprehensive regime for sustainable ocean governance has yet been achieved is that different institutions are responsible for each of the various types of ocean use. At the highest political level, first of all, there are various institutions under the umbrella of the United Nations (UN) dealing with the various different use and protection aspects of the ocean; for example, the ISA headquartered in Kingston, Jamaica, and the International Maritime Organization (IMO) in London which lays down the rules for international commercial ship-ping. These are set out in international treaties, the conventions.

One example is the Ballast Water Management Convention. Ballast water is stored in special ships' tanks. Its purpose is to keep ships stable when they are empty or lightly loaded. Depending on whether a ship in port is being loaded or unloaded, it will either pump ballast water into its tank or drain it back into the coastal waters. Along with this ballast water, in turn, marine organisms can be carried from one part of the world to another. If they become established there and suppress native species, this can change the nature of entire habitats. In order to combat the incursion of alien species, known as bio-invasion, under the terms of the convention, ballast water must be purified in future with special treatment plants on board ship.

The IMO also has the right, upon request from member states, to place Particularly Sensitive Sea Areas (PSSAs) under protection. These are areas where shipping is restricted or prohibited in order to protect important



3.4 > Currently there are many different institutions dealing with the oceans, which makes it harder to establish a unified approach to marine protection. These institutions can be categorized into different governance levels: 1. globally responsible UN authorities which deal exclusively with oceans, such as the International Maritime Organization (IMO); 2. UN authorities like the Food and Agricultural Organization (FAO) which deal principally with other aspects, only partly relating to the sea; 3. international organizations dealing for the most part with geographically delimited sea regions, such as the Oslo-Paris Convention (OSPAR) responsible for the Northeast Atlantic; 4. non-governmental institutions. Beyond this, every national state is responsible for protecting its territorial waters itself by adopting relevant laws. This nation-state level of governance is not shown here.

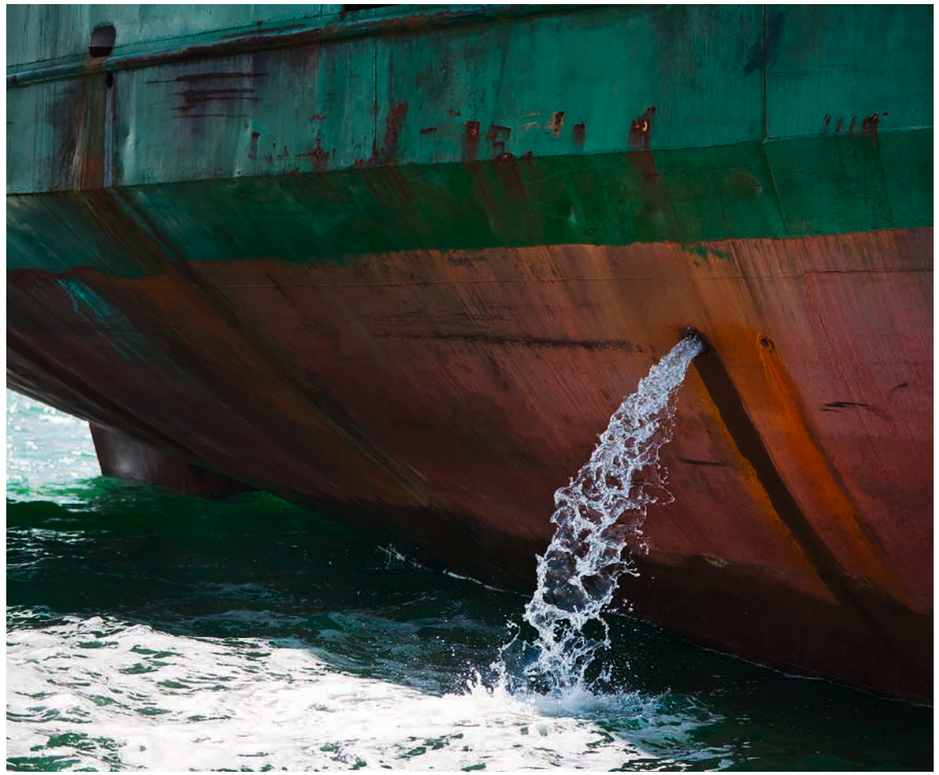
CBD Convention on Biological Diversity **CCAMLR** Commission for the Conservation of Antarctic Marine Living Resources **CITES** Convention on International Trade in Endangered Species of Wild Fauna and Flora **CLCS** Commission on the Limits of the Continental Shelf **CMS** Convention on Migratory Species **COL** Consortium for Ocean Leadership (NGO comprising various marine research institutions) **COS** Center for Oceans Solutions (professional training institution of various marine research institutions) **CSI** Cetacean Society International (NGO for the protection of whales) **DESA** Department of Economic and Social Affairs (of the UN) **DOALOS** Division for Ocean Affairs and the Law of the Sea **DSCC** Deep Sea Conservation Coalition **EMSEA** European Marine Science Educators Association **EU** European Union **FAO** Food and Agriculture Organization **GEF** Global Environment Facility **GESAMP** Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection **GOBI** Global Ocean Biodiversity Initiative **GOF** Global Ocean Forum **Greenpeace** NGO for protection of the natural environment **HELCOM** Helsinki Commission (inter-state commission for protection of the Baltic Sea) **HLPF** High-Level Political Forum on Sustainable Development (UN forum) **ICES** International Council for the Exploration of the Sea **ICRI** International Coral Reef Initiative **ICSF** International Collective in Support of Fishworkers **ICSU** International Council for Science **ICSU/SCOR** Scientific Committee on Oceanic Research **ICSU/SCAR** Scientific Committee on Antarctic Research **IMBER** Integrated Marine Biogeochemistry and Ecosystem Research **IMO** International Maritime Organization **IOC** Intergovernmental Oceanographic Commission (under the auspices of UNESCO) **IOC CARIBE** IOC Sub-Commission for the Caribbean and Adjacent Regions **IOC WESTPAC** IOC Sub-Commission for the Western Pacific **IOC AFRICA** IOC Sub-Commission for Africa and the Adjacent Island States **IOI** International Ocean Institute (NGO for the protection of the oceans) **IPSO** International Programme on the State of the Ocean **ISA** International Seabed Authority **IUCN** International Union for Conservation of Nature and Natural Resources **IWC** International Whaling Commission **MBI** Monaco Blue Initiative (NGO promoting the creation of marine protected areas) **MEA** Multilateral Environmental Agreement **OCR** Ocean Conservation Research (NGO for the abatement of ocean noise pollution) **OCEANA** NGO for the conservation of marine biodiversity **OSPAR** Oslo and Paris Convention (Convention on protection of the North-East Atlantic and the North Sea) **PacMara** Pacific Marine Analysis and Research Association **PEMSEA** Partnerships in Environmental Management for the Seas of East Asia **PICES** North Pacific Marine Science Organization **PEW Charitable Trusts** (independent non-profit foundation) **RFMOs** Regional Fisheries Management Organizations **RSP** Regional Seas Programmes **SOI** Sustainable Ocean Initiative **UN** United Nations **UNDG** UN Development Group **UNDP** UN Development Programme **UNEP** UN Environment Programme **UNESCO** UN Educational, Scientific and Cultural Organization **UNGA** United Nations General Assembly **UN-OHRLLS** UN Office of the High Representative for the Least Developed Countries, Landlocked Developing Countries and Small Island Developing States **UNSG** Secretary-General of the UN **WOC** World Ocean Council **WWF** World Wide Fund (NGO for nature conservation)

fishing grounds, whale breeding grounds or areas of ecological value.

Another example of a convention that was passed under the umbrella of the IMO is the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78). In Annex V, in force since 1988, it prescribes to shipping which wastes have to be collected on board. According to MARPOL, for instance, the disposal of leftover food may only take place outside the 12-nautical-mile zone. Plastic waste, on the other hand, may not be thrown overboard at all according to Annex III.

The examples show that with UN authorities like the IMO or ISA taking such sectoral responsibility, it is perfectly possible to attain individual marine protection goals. But at times, having governance subdivided into different sectors can also be a hindrance. For example, no UN authority is currently able to place sea areas under complete protection – i.e. to impose protection which covers the sea floor, water column and fish stocks alike, which regulates shipping, and which prohibits other uses such as drilling for natural gas and petroleum.

Moreover, on a global level there are additional UN authorities whose tasks only partly encompass marine aspects. The United Nations Food and Agricultural Organization (FAO), for instance, records data on the condition of fish stocks worldwide. Over the years it has published numerous guidelines for responsible fisheries and sustainable fishing, but these are merely recommendations and in no way legally binding. Member states are left to decide for themselves whether or not to abide by them.



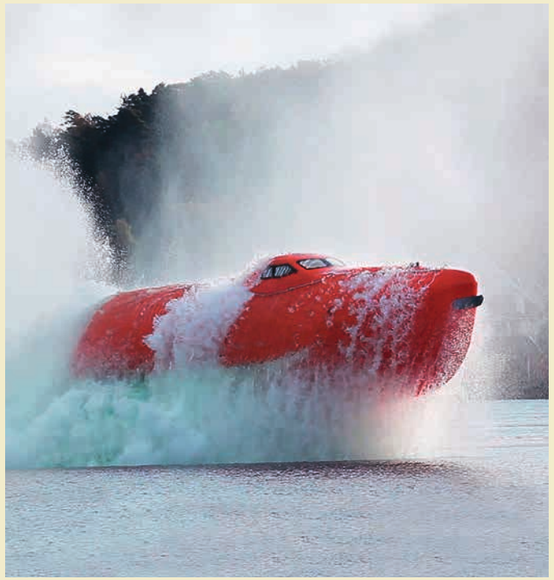
3.5 > Ballast water being pumped out in a harbour. Ballast water can transport bio-invaders from one ecosystem into another. Some of the organisms reproduce so prolifically in foreign waters that they suppress local species. The International Maritime Organization's International Ballast Water Management Convention therefore stipulates that ballast water must be purified in future.

The ground rules of international ocean governance

On the international level, the United Nations (UN) in particular and its various organs are currently responsible for ocean governance. The United Nations is an international organization of 193 countries with headquarters in New York. Among its most important tasks are safeguarding world peace, adherence to international law, protection of human rights and the promotion of international cooperation. Another of the objectives defined by the international community within the framework of the UN is, importantly, the protection and sustainable use of the ocean. The most important UN regime on the theme of the ocean is the Convention on the Law of the Sea (UNCLOS). UNCLOS is treated as a constitution for the oceans. It was passed by the UN in 1982 and entered into force in 1994. It sets out the international legal framework governing the principles for the use of marine resources and protection of the marine environment by law. UNCLOS forms the legal umbrella which overarches the work of all the UN organs dealing wholly or partly with the theme of the ocean.

One example of a UN institution governing parts of the ocean according to UNCLOS is the International Seabed Authority (ISA). The ISA regulates the exploration and mining of mineral resources (ores) on the seabeds of international waters. Under the terms of UNCLOS these resources in the high seas are the "common heritage of mankind", which should benefit all states equally. Under UNCLOS, the ISA has the task of supervising the equitable distribution of these resources, and grants seamining licences accordingly. Beyond this it is responsible for guarding against any destruction of marine habitats on the sea floor as a result of sea mining. So far countries have only had rights to explore the sea floor. Then, from 2016, the first licences for mining can be granted. The ISA is acknowledged today as a successful example of the clearly regulated use of marine resources. Law scholars praise the fact that in setting up the ISA, for the first time in history humankind has succeeded in controlling the use of a resource before extraction commences.

Another example of functioning multinational ocean governance under the umbrella of the Convention on the Law of the Sea is the work of the International Maritime Organization (IMO). In the course of time the IMO has passed several conventions which regulate shipping throughout the world. These include conventions which contribute to maritime safety or are intended to protect the ocean against pollution from shipping. The safety of shipping is regulated by the 1974 International Convention for the Safety of Life at Sea (SOLAS). SOLAS stipulates, for example, how many lifeboats ship must have on board and how often these should be serviced. The International Convention for the Prevention of Pollution from Ships (MARPOL 73/78), for its part, is intended to prevent marine pollution and particularly of coastal waters by shipping. MARPOL stipulates, for example, that in Special Areas it is prohibited to discharge liquid cargo or oil residues from the ship's engine



3.6 > Endurance test of a rescue boat: under the SOLAS Convention, lifeboats must undergo certain checks. One of these is the drop test, where a fully-loaded lifeboat is dropped into the water from a height of several metres.

(spent oil) into the sea. These Special Areas include the Baltic Sea, the Mediterranean and the Black Sea, among others. In the waters of the high seas, however, tank cleaning is permitted under the terms of MARPOL. Ships' masters must comply with MARPOL by recording in oil logs precisely where and how they have disposed of anything.

Every coastal state oversees compliance with the standards of the IMO conventions for itself. For instance, the local port authorities of any country are permitted to check all ships for compliance with the SOLAS or MARPOL rules. If a ship's master breaches the regulation, a ship can be detained in harbour. As a result of this mechanism known as port state control (PSC), today most ship-owners comply with the rules of the IMO conventions. Shipping companies who flout them are placed on blacklists, and their ships subjected to especially thorough scrutiny. That said, the specifics of how strictly ships are inspected differ from country to country. Australia, South Africa, the USA, the Member States of the EU and the countries of South America take these checks very seriously nowadays.

Port state control not only checks compliance with the IMO standards but also with the provisions of other UN organs, such as the International Labour Organization (ILO), for example. The ILO, based in Geneva, is responsible for employees in a wide range of occupational fields worldwide, and its work includes representing the rights of mariners. Since many mariners had a long history of poor working conditions, due to factors like low pay, long working hours and a lack of social benefits, in 2006 the ILO passed the Consolidated Maritime Labour Convention, which entered into force in 2013. It sets out international minimum standards for the working conditions of mariners. Its aim is to prevent workers from being exploited. In Germany, compliance with this convention is verified during port state control by the trade supervision office or the public health office. In other words, during the port state control, staff from different state authorities may well be in attendance.

Multinational governance can even work when individual states end up in conflict with each other. Disputes between countries over sea borders, for example, have arisen in the past and will arise time and time again; in other cases, ships are detained for various reasons. A well-known example is the case of the *Arctic Sunrise*. In 2013 this ship belonging to the environmental organization Greenpeace and sailing under the Netherlands flag was detained with all its crew by Russian border security. Previously staff of the organization had boarded the oil platform of the Russian energy group Gazprom to protest against oil drilling in the Arctic. Russia accused the activists of piracy. The Netherlands lodged a demand for Russia to release the ship and its crew.

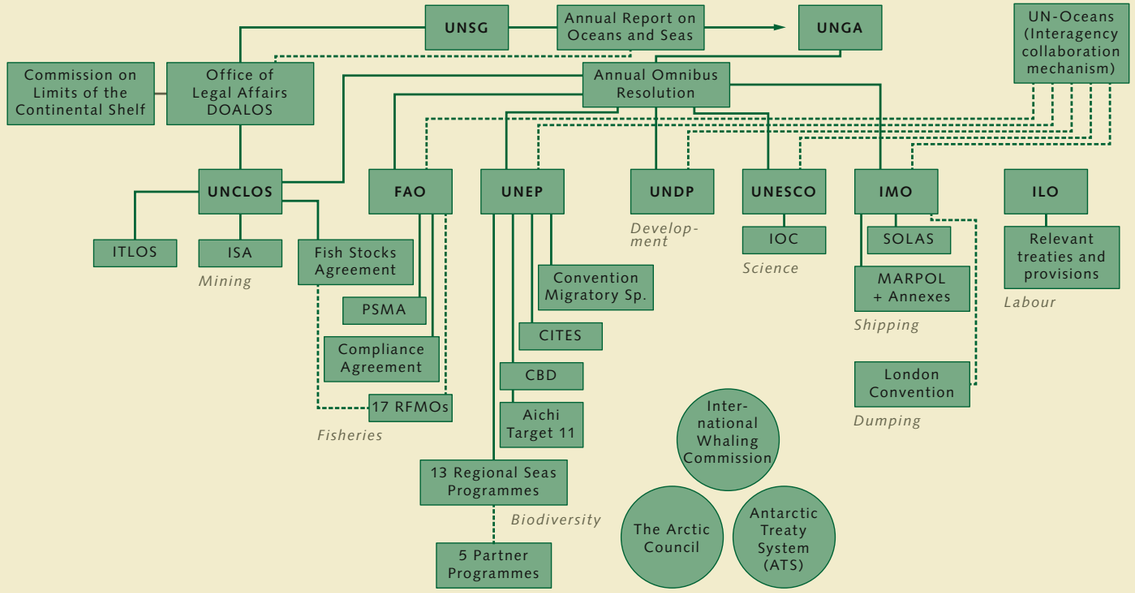
In cases like this, the two countries can have their dispute heard in court. In this regard they have a choice of options. They can either take their case to the International Court of Justice (ICJ) of the United Nations in The Hague, which also negotiates marine law disputes. Or they can invoke the International Tribunal for the Law of the Sea (ITLOS) in Hamburg, which was founded within the framework of the Convention on the Law of the Sea in 1996, specifically for disputes with a bearing on the ocean. 23 cases have been dealt with at ITLOS to date, one such case being that of the *Arctic Sunrise*. ITLOS came to the conclusion in November 2013 that the accusation of piracy was untenable, and ordered Russia to release the ship. Russia was slow to respond. Initially, crew members were set free one by one over a period of several weeks. Finally, Russia also released the ship.

In principle, countries can only take a case before ITLOS if both parties have ratified UNCLOS, which was applicable in the case of the *Arctic Sunrise*. Russia's release of the ship and crew was also attributable to strong public pressure, say legal scholars. According to the experts' opinion, it is especially difficult for the global superpowers to submit to independently administered justice and an international legal regime. Unlike Russia and China, the USA has not ratified UNCLOS to this day – with the consequence that it only has a weak voice in matters relating to the law of the sea.

Although there are international bodies such as the ICJ and the ITLOS which can settle disputes with a bearing on the ocean, ultimately there is no authority which could enforce the law with finality. Even if a country that has ratified the UNCLOS is sentenced by ITLOS, it can refuse to accept the judgement. In such a case pressure can only be exerted on the country through political and diplomatic channels. Therefore experts in the law of the sea consider UNCLOS and ITLOS to be an international regime with some weaknesses.

3.7 > The International Tribunal for the Law of the Sea (ITLOS) has its seat in the Hanseatic city of Hamburg. The institution was founded in 1996.

Ocean governance in a wide arena



3.8 > At the level of the United Nations alone, many organizations are wholly or partially involved with aspects of the ocean. Solid lines indicate direct dependencies between bodies and international agreements. Dashed lines indicate functional links. Intergovernmental organizations that do not directly form part of the UN system (such as the International Whaling Commission) are shown separately. "Aichi Target 11" refers to the goal adopted at the biodiversity conference in Aichi, Japan, of assigning protected status to 10 per cent of marine areas by the year 2020.

Today many institutions under the umbrella of the UN are dealing with the aspect of ocean governance. The most important regime is the UN Convention on the Law of the Sea (UNCLOS) which sets out the international ground rules for marine policy. Under the umbrella of the UN and UNCLOS, responsibilities in the marine context can be roughly broken down into the areas of labour law, biodiversity, development (particularly in developing countries and emerging economies), fisheries, sea mining, shipping and science. The standards of the responsible UN bodies or of the respective international agreements are not all legally binding to the same degree. UNCLOS requires member states of the UN to protect the sea but leaves it to them to transpose marine protection into national laws. The rules of the IMO for shipping, in contrast, are binding and can be enforced in the event of a breach. Ships can also be reined in if ships' masters circumvent IMO regulations. In many other cases, however, there is no means of sanctioning misconduct. One example is the Convention on Biological Diversity (CBD), which entered into force in 1993 and today has 196 parties. It has three objectives: conservation of biodiversity; sustainable use of the components of biodiversity; and fair and equitable sharing of the benefits arising from the use of genetic resources. The difficulty surrounding implementation of this convention is that the CBD is viewed as a framework agreement with general objectives. Unlike UNCLOS, the ISA or the IMO, there are no administrative structures for the CBD. There is not even a headquarters with its own administration, but merely conferences at which goals are defined. In accordance with the CBD, signatory states and groups of states like the EU have to enshrine the CBD goals in their respective legislation. However, the convention lacks clear criteria, limit values, sanction measures or deadlines. The upshot of all this is that so far many nations have no comprehensive strategies for the protection of biodiversity – either on land or in the ocean.

Agreements safeguard particular interests

On the regional level, too, the sectoral view of the ocean is predominant. Thus there are almost 600 agreements in existence today which have been passed by multiple states and which regulate the use or protection of the ocean in a delimited region. Examples are the "Agreement between the Government of the Russian Federation and the Republic Poland Government about cooperation in pollution abatement of the Baltic Sea, including the Kaliningrad (Vislinsky) Gulf, by oil and other harmful substances" or the "Agreement on Fisheries between the Government of Australia and the Government of Japan concerning Japanese Tuna Long Line Fishing". The large number of agreements does not necessarily constitute evidence of any comprehensive regional marine protection or sustainable ocean governance regime. It much rather underlines that many states pursue particular interests, which have been safeguarded over the course of time by means of agreements tailored to that purpose.

How states cooperate on regional marine protection

Regional Seas Programmes (RSP) are another mechanism of particular significance for regional ocean governance. These are programmes in which the coastal states of particular sea regions have joined forces to improve marine protection in their region. The nature of the cooperation and the protection objectives are usually set down in regional agreements. These programmes were initiated in the 1970s by the United Nations Environment Programme (UNEP). Today there are 13 Regional Seas Programmes in which 143 countries participate. Their focus is on the following 18 sea regions: Antarctica, the Arabian-Persian region, the Arctic, the Caribbean, the Caspian Sea, the Mediterranean, the Northeast Atlantic, the Northeast Pacific, the Northwest Pacific, East Africa, East Asia, the Baltic Sea, the Pacific, the Red Sea and the Gulf of Aden, the Black Sea, South Asia, the Southeast Pacific and West Africa.

In the view of experts worldwide, however, there have been only a few positive examples of good ocean governance to date within the framework of the Regional Seas Programmes. These include the Helsinki Commission (HELCOM) which is responsible for the protection of the Baltic Sea, and the Oslo-Paris Convention (OSPAR) which covers the North Sea and the Northeast Atlantic. Membership of OSPAR consists of several western and northern European countries, including the European Union, which have reached agreement to coordinate their marine protection efforts in the region of Biscay, the North Sea and the Northeast Atlantic through the OSPAR office in London.

Under the auspices of OSPAR, progress has been made in areas such as designating areas of the high seas as marine protected areas (MPAs) even though these are located outside the exclusive economic zones of the OSPAR contracting parties. One example is the Charlie Gibbs MPA, a highly species-rich deep-sea habitat located in the Atlantic between Iceland and the Azores. Experts had feared that this habitat could be destroyed by sea-floor trawl fishing with drag nets. OSPAR and NEAFC, the regional fisheries management organization responsible for the sea region, came to an agreement to comply with the FAO guidelines on sea-floor fishing. Among other provisions, these require the complete cessation of sea-floor fishing in areas of ecological significance such as species-rich **seamounts** or communities of cold-water corals or sponges. In this way the Charlie Gibbs MPA was protected from future sea-floor fishing in accordance with the FAO guidelines. But in the water column above it, fish may still be caught as before. It is problematic that member states which do not belong to the corresponding RFMO, in this case the NEAFC, cannot be obliged to respect a MPA like the Charlie Gibbs Area. This makes it quite conceivable that ships from other countries might carry on sea-floor fishing in a MPA. Thanks to aerial and space surveillance and the automatic ship recognition system (Automatic Identification System, AIS) whereby a transmitter on board reports ships' data, e.g. name and position, fishery vessels in foreign waters can nevertheless be detected. For the Charlie Gibbs area an environmental protection organization has set itself the task of using AIS to monitor shipping activity.

Charlie Gibbs Marine Protection Area
The Charlie Gibbs Marine Protection Area is located on what is known as the Mid-Atlantic Ridge. It is a location where continental plates are drift-ing apart from each other so that magma from the Earth's core repeatedly flows into the sea. As a result, mountainous structures on the sea floor grow up over time and form a ridge. Individual sections of this ridge are referred to as fracture zones. Fracture zones are normally named after the research ships that studied them. In the case of the Charlie Gibbs Marine Protection Area, it was the *Josiah Willard Gibbs* which spent an extended stay in the area in 1968. The affix "Charlie" comes from the nearby weather station of the same name.

3.9 > The Charlie Gibbs Marine Protection Area in the Atlantic is populated by many bizarre deep-sea creatures like this acorn worm (*Yoda purpurata*). The area is special because it is one of the few protected areas in international waters.

Gratifyingly, on the evidence so far, the area is obviously being respected by all nations. Ships engaging in sea-floor trawling have not been detected.

But another example demonstrates that the negotiation partners do not reach consensus in every case. In the Atlantic there are other areas of ecological value apart from Charlie Gibbs, which have unilaterally been declared MPAs by OSPAR but are not accepted by all NEAFC member states; one such area is the Josephine Seamount, which is located southwest of Portugal's EEZ. Portugal is laying claim to the continental shelf beyond its EEZ and accordingly wishes to extend its mineral extraction rights to 350 nautical miles offshore – out beyond the Josephine Seamount area. For cases like this, the NEAFC regulation makes provision to grant the affected coastal state fishery rights in its continental shelf area – although the continental shelf provision pursuant to UNCLOS has nothing whatever to do with fishery but relates exclusively to mineral resources. On that basis, Portugal may carry on fishery with long lines in this case. During internal negotiations within the NEAFC over the establishment of a MPA at the Josephine Seamount, Portugal predictably expressed its opposition. Since other member countries had abstained in the last negotiations, there is currently no majority within the NEAFC in favour of the MPA. Consequently other countries have continued to engage in sea-floor trawling in the area. The most recent sightings were of Spanish and Latvian ships.

Charlie Gibbs thus remains one of the few examples in the world of successful marine protection within the framework of the Regional Seas Programmes. In other cases, marine protection failed due to a lack of cooperation among states or because it was not made the foremost priority. One example is the Abidjan Convention responsible for the African Atlantic coast between Mauritania and South Africa, which entered into force in 1984. Due in no small part to civil wars in Côte d'Ivoire, Liberia and Sierra Leone as well as a lack of technical equipment and money, little progress has been made towards marine protection objectives since the convention took force. For some years, however, the member countries of the Abidjan Convention have been stepping up their efforts to revitalize marine protection. A first step is to identify, and systematically to document, sensitive and protection-worthy areas of the sea. This applies particularly to a large sea area which was defined in the Abidjan Convention as a Large Marine Ecosystem (LME) and extends beyond the EEZs of several West African countries. This area, the Canary Current Large Marine Ecosystem (CCLME), is especially productive because it is where the Canary Current upwells nutrients from the deep sea to the water

Marine protected areas – not enough for large-scale protection

Marine protected areas (MPAs) are an instrument for placing particular areas under protection. MPAs can be established both in international and in territorial waters of coastal states. Generally they are used to pursue individual protection objectives. Thus the establishment of a MPA does not mean that the sea area may no longer be used at all and is protected in every respect. MPAs are designated, for example, for the purpose of allowing overfished fish stocks to recover. In other cases, trawl fishing is prohibited in order to conserve sensitive habitats on the sea floor. But in the water column above it, fishing continues to be allowed. So most MPAs do not give comprehensive protection from the sea floor to the water surface. Shipping in a sea area cannot be restricted indiscriminately, for example, because freedom of shipping is applicable in international waters and in the exclusive economic zones. Currently all MPAs have a total area of around 12 million square kilometres, which amounts to just 3.4 per cent of the global ocean surface. Of the area classified as high seas, just one per cent of the ocean surface enjoys MPA protection. On this evidence, humankind is still far from the conservation goal set by the United Nations at the biodiversity conference in Nagoya, Japan, in 2010: there it was agreed that at least 10 per cent of the global ocean surface should be placed under protection by the year 2020.

National states can designate MPAs for their own waters. In order to establish a MPA in international waters, on the other hand, the countries which make use of the sea area must reach agreement on the common protection objective, as in the case of the NEAFC and the Charlie Gibbs area. In a few cases to date, this has delayed or completely blocked the designation of MPAs. In the opinion of experts, there are too few protected areas at present. Moreover, the few that exist are often very isolated from one another. In keeping with the principles of species and habitat conservation, it would make more sense to link protected areas in a trans-regional network because many species meriting protection are often wide-ranging in their distribution.

Large Marine Ecosystems
To improve the protection of transboundary coastal regions, the US National Oceanic and Atmospheric Administration (NOAA) developed the concept of large marine ecosystems (LMEs) in the 1990s. The Earth's coastal sea areas were divided up into 64 LMEs. Each LME is characterized by typical flora and fauna. Many LMEs are especially productive, being supplied with plentiful nutrients by rivers or upwelling currents. These produce 95 per cent of global fish biomass. The LME concept takes account of socio-economic as well as biological aspects.

surface. Accordingly there are high levels of algal growth, high primary production, and large quantities of zooplankton and fish. A first step towards protection of the CCLME is to make detailed maps of the area with all its habitats. To this end, in a workshop organized by the Abidjan Convention, staff were trained in geo-information systems (GIS). Beyond this, the convention supports the member countries in which oil is drilled to produce sensitivity maps. These record how sensitively particular coastal areas react to oil pollution incidents. In the case of an oil spill, these could be used to help relief workers protect areas of particular value with oil booms.

East Asia – hotspot of environmental degradation or of marine protection?

Under the umbrella of the United Nations Development Programme (UNDP), too, regional marine protection initiatives involving multiple countries have been brought into being over the years. Covering the East Asian region, for example, is PEMSEA (Partnerships in Environmental Management for the Seas of East Asia). PEMSEA is classified as a non-governmental organization but is a large network in which very different stakeholder representatives and institutions cooperate: representatives of national governments or local administrations, companies, educational establishments, research institutions and sponsors. The PEMSEA area extends from Thailand across Indonesia and the Philippines to the coasts of China and Japan. Within this vast expanse there are five major sea areas which are of both ecological and economic significance: the East China Sea, the Yellow Sea, the South China Sea, the Sulu and Celebes Sea and the waters around Indonesia. According to PEMSEA data around 1.5 billion people in this region live within a 100-kilometre distance of the coast. Parts of this region have undergone impressive economic development in recent years. Others, however, are plagued by deep poverty. PEMSEA considers the main threats to the marine environment to be marine pollution with plastic waste and effluents from rivers, municipalities and industry, but also nutrients from agriculture. Added to this are the issues of overfishing, destruction of coastal wetlands by building projects, and careless fishery with resultant damage to sea-floor habitats such as coral reefs.

Especially affected are industrialized and densely populated ocean bights and straits, where access to the open sea is constrained so that water can only be exchanged slowly. These include the approximately 400-kilometre-long Bohai Bay, a coastal location surrounded by several urban centres and adjacent to Beijing; the approximately 50-kilometre wide Manila Bay off the Philippines' principal island of Luzon; and the narrow Malacca Strait between Malaysia and the Indonesian island of Sumatra. Within the PEMSEA network there are very different approaches aiming to improve marine protection in these three regions and in other areas as well. The Bohai Bay region, which is already extremely industrialized today, is primarily threatened by pollutants and nutrients transported from the hinterland by around 40 rivers. Pollution in the region is to be reduced by constructing large purification plants. Another problem in the Bohai Bay is the loss of wetland areas in the estuary delta of the Yellow River due to the construction of tourist amenities, residential settlements, industrial areas and large aquaculture facilities.

Likewise, the Bay of Manila is surrounded by heavily industrialized and densely settled areas. Moreover, tourism and fishery are important branches of the economy. As in the Bohai Bay, water pollution and the destruction of coastal habitats are the key problems. Within the framework of PEMSEA, a strategy for Integrated Coastal Zone Management (ICZM) for the Bay of Manila is currently being developed. ICZM is based on a concept that many countries worldwide have been pursuing for some years now. It sets out to reconcile the different interests that exist in a coastal area. The goal is to bring the use of the sea and the conservation of nature into harmony as far as possible by weighing up and offsetting environmental protection, the needs of the population and the interests of business people against one another. Such strategies are elaborated by individual states in many cases. In the case of PEMSEA, however, efforts are definitely geared towards joint ICZM; for example, by bringing partners from very different nations together in workshops.

3.10 > The densely settled and, in places, heavily industrialized Bay of Manila is one of the most severely polluted regions of the Philippines. Plastic detritus is the most striking sign of sea pollution in this coastal area.

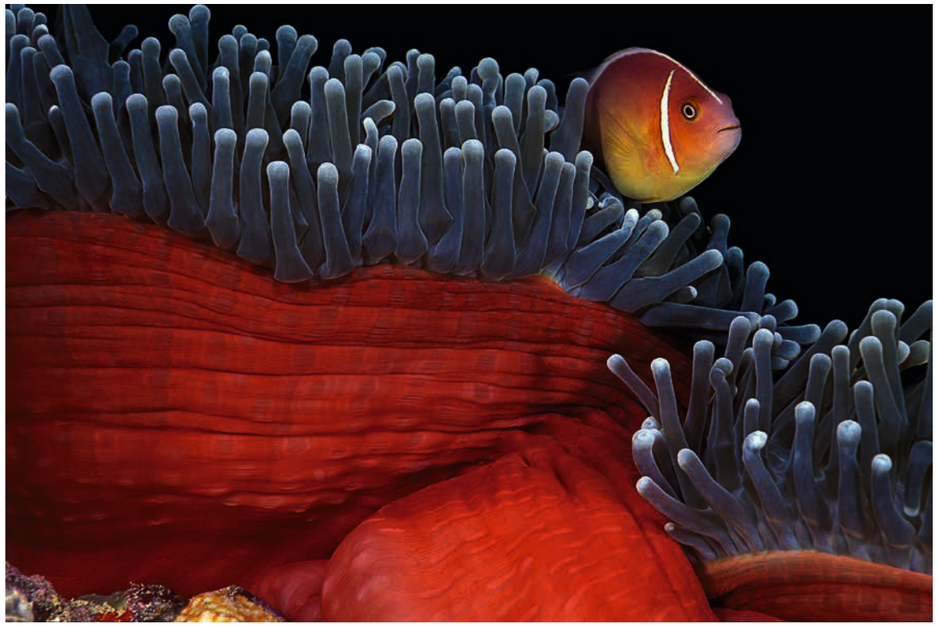
Special value is also placed on the education of the population. In the workshops, for example, training is being provided to teachers, coastguard staff and press workers in informing the population about the correct way to deal with waste, which is frequently still being thrown into the sea at present. Depending on the local circumstances, the focuses of marine protection may well vary. In the Bay of Manila, projects are currently planned on the reforestation of mangroves and the establishment of protected areas for fish and turtles.

How successfully PEMSEA works in reality in the different regions will remain to be seen in years to come. A crucial aspect by any standard is whether China, as the largest and most powerful economic power in the region, is willing and able to practise marine environmental protection.

Nation states themselves determine the fate of their territorial waters

Alongside these regional forms, of course, ocean governance also takes place on a nation-state level. This generally extends to the territorial sea of a country, and to its exclusive economic zone, for according to UNCLOS every individual state is to enshrine marine protection in its national constitution by means of laws. It is clear from comparisons of different coastal areas in the world that marine protection enjoys a very different status from one country to another despite national environmental laws.

In 2004, for instance, Australia established a fishery exclusion zone around the Great Barrier Reef, the coral reef along the northeast coast of Australia, in order to protect shrinking fish stocks. This "no-take zone" (NTZ) with



3.11 > A major part of Australia's Great Barrier Reef is closed to fisheries. The aim of this is to protect its native organisms such as the Pink Anemonefish *Amphiprion perideraion*.

an area of 115 000 square kilometres is one of the largest worldwide. Although it caused profits from fishery to fall, many fish stocks had recovered just two years after the ban and, according to scientific analyses, economic benefits have accrued to tourism because the region has become more interesting for divers, for example. Nevertheless, even established protected areas like that of the Great Barrier Reef can find themselves at risk. It so happens that with support from the current Australian government, preparations are being made for the building of a coal port. The silt produced by the excavations will be dumped in the vicinity of the reef. Conservationists are up in arms about this plan.

According to a study, especially heavy pollution is found in the coastal waters off the East African coast, such as the sea area off the Tanzanian capital of Dar es Salaam. The study shows that the waters are polluted in particular with bacteria from faecal matter, with nutrients from agriculture (crop production, livestock rearing and feed production) and with metals and long-lived (persistent) pollutants from the chemicals industry. Indeed, 80 per cent of Tanzania's industrial plants are concentrated in Dar es Salaam, including metal processing and battery, glass and paper factories, which mostly discharge their effluents unpurified. Since there are no modern purification facilities in Dar es Salaam, bacterial impurities and contaminants usually find their way directly from sewerage pipes into the sea. According to a study by Tanzanian marine researchers, the seafood there was inedible and the coastal waters downstream of the effluents were unsuitable for bathing. Regardless of this, some beaches in the area are still used by tourists. Although there are various infiltration basins in the city which collect wastewater and allow sewage sludge to settle, these are poorly sealed, with the result that polluted water penetrates the soil and simply drains away. Moreover, the existing capacities fall short by some margin for the city which has grown drastically in recent decades. Between 1985 and 2010 alone, the population doubled. In 2012 the population grew by 6.7 per cent from the previous year.

A tool kit for good governance

Many countries are a very long way from practising good ocean governance and sustainable use of their sea areas. The separation between different sectors and domains of competence and between the global, international and national levels makes it all the more difficult to join forces and comprehensively protect the marine environment. To accomplish good ocean governance, the following criteria – which are applicable to all domains of competence and on all levels in equal measure – should be satisfied:

SYSTEMIC APPROACH: Up until now, various marine aspects have been considered separately from each other. Economic objectives such as fishery, the construction of port and industry facilities or hotels are pursued without regard to the consequences for the environment or the needs of the coastal population. The systemic approach, on the other hand, takes into consideration that economic, social and environmental aspects are closely interwoven in one system. It also honours the fact that habitats are very complex structures in which many animal species are interconnected in food webs. Whereas past thinking about the use of ecosystem services often only considered individual organisms, today efforts are made to take a view of the ecosystem as a whole. In fisheries, for example, for a long time only the population sizes of individual fish species were of interest. In future, fishing shall increasingly be managed with prudent regard for the ecosystem as a whole. An example of this is to refrain from using heavy fishing gear that damages the sea floor.

PRECAUTIONARY APPROACH: In many cases, scientists today cannot say with certainty how severely endangered an animal species or habitat is or, for example, how dangerous a chemical substance is. According to the precautionary approach, humans should act with foresight. One example is overfishing. Fishery researchers cannot count fish. They have to make use of sample catches and mathematical models to estimate the size of a fish population. For this reason, according to the precautionary approach they recommend setting catch quotas cautiously in order to prevent such severe reduction of a fish population that it no longer produces enough offspring and succumbs to overfishing. Furthermore, researchers recommend reducing the emission or use of chemicals even if the substances are only suspected of being harmful to living organisms.

ADAPTIVE MANAGEMENT: The biological, biochemical and physical processes in the sea are so complex that so far scientists have only gained a partial understanding of them. Equally, the changes that will occur in the wake of climate change are virtually impossible for scientists to envision today. Further research will bring new insights which must also be taken into account in future as part of ocean governance. It must therefore be shaped so as to be adaptable in the light of new scientific findings.

TRANSPARENT INFORMATION: Scientists have conducted numerous marine research studies and pulled together thousands of facts to date. So far it has been extremely difficult to access much of this data because it has not been recorded centrally but stored in the offices or labs of individual researchers and thus widely dispersed. Often, too, data disappears in the files once projects have run their course. It is therefore a prerequisite for good ocean governance and, in particular, adaptive management that scientific findings are made rapidly accessible to the public and to policymakers. How this can work is demonstrated by the Marine Strategy Framework Directive (MSFD), the current marine protection strategy of the European Union (EU). This obliges the authorities of the EU Member States to make all data on the condition of the sea in their exclusive economic zones generally accessible on Internet portals by 2020. Thus, in future it will take just a few clicks to be able to compare data on different environmental parameters from different years – on degradation of the sea floor by fisheries, on species diversity in certain European sea areas, or on the pollutant load of the waters. Environmental policy decisions and measures can be taken on a sounder basis. Applications to carry out construction projects in the sea, such as installing offshore wind farms, can be processed more quickly; not least,

because the competent authorities can more easily ascertain whether particularly sensitive or protection-worthy sea areas are affected.

CLEAR ALLOCATION OF USAGE RIGHTS: To prevent overuse of the collective resource of the sea, because many countries as well as corporations exploit it excessively, ocean governance should ensure that usage rights are clearly distributed. In certain circumstances, this also involves excluding potential users. One example is the allocation of fishery rights by one of the Regional Fisheries Management Organizations (RFMO). These regulate fishery in a sea area and ensure that catch quotas are distributed among member states. Other nations at greater distances from the corresponding areas do not normally receive permission to fish. The aim of this is to prevent fish stocks in international waters – which are marine commons – from being overfished.

GLOBAL COOPERATION MECHANISMS: The sea cannot be confined by borders. Many problems cut across borders or even have a global dimension, as the phenomena of ocean warming and acidification show. Ocean governance can only work well if the interests of the many private, state, local or regional institutions and stakeholder groups can successfully be reconciled with each other. One precondition for this is that global regimes define marine protection goals more clearly than is the case today, for instance in UNCLOS. On the other hand, these regimes must be broadly framed and flexible enough to be applicable to different sea regions.

SUBSIDIARY AND PARTICIPATORY DECISION-MAKING STRUCTURES: According to the systemic approach, all interests should be given due consideration in order to gain the consent of all parties involved and to increase the acceptance of any decision. Marine protection is a global challenge. Nevertheless, the interests of the local people in the various coastal regions must be taken into account, too. Marine protection works well in situ if the people can see the logic of the protection idea. This is particularly important when it results in curtailment of the population's usage rights. Fishers who earn a living from local fishery, for example, should have a say in what practices should be adopted to protect coral reefs – such as avoiding shallow areas in order to prevent destruction caused by boats, or refraining from dropping anchor. By the same token, they can help to determine what constitutes alternative employment of equal value in the event that fishery should be prohibited entirely for the protection of the corals.

INCENTIVES FOR INNOVATIONS: In keeping with sustainable ocean governance, entrepreneurs or other stakeholder groups should be rewarded for making sustainable use of marine ecosystems and developing corresponding business models for the prudent use of the sea. In addition, development programmes should promote research, education and technology aligned with marine protection objectives. Particularly in developing countries, marine protection could be advanced by transferring knowledge and sustainable technologies.

FAIR DISTRIBUTION MECHANISMS: Both profits from the use of marine ecosystem services and the costs of protecting the marine environment should be distributed equitably. This would prevent individual stakeholder groups from capitalizing on exploitation of the marine commons. Equally, the costs of monitoring the environmental status of the ocean should be borne collectively by the various users. This distribution of costs and benefits should take place at all levels of ocean governance, both between different countries and between the different population groups within a country. Ultimately, intergenerational distributive justice should also be taken into consideration, so that all ecosystem services will remain available to future generations without restriction.

CONFLICT RESOLUTION MECHANISMS: Conflict resolution mechanisms are necessary in order to reconcile the diverse interests of different users. In this process, ocean governance should offer mechanisms for solving conflicts both between states and within individual countries. Nowadays there are many examples of individual stakeholder groups within countries exploiting natural capital

3.12 > Wind farms in the sea can make a substantial contribution to the electricity supply. Before they are constructed, though, sites should always be assessed to ensure that sensitive marine habitats will not be destroyed.

while sizeable population groups are left empty-handed. This is happening in oil-rich Nigeria, for example. The crux of the problem is that the Nigerian government does not distribute the profits from the oil business equitably. It negotiates cooperation agreements and drilling licences with multinational oil corporations and receives annual revenues amounting to billions. Despite the existence of a distribution ratio whereby the dollar profits are supposed to be shared out between the national budget, regional governments and local administrations, very little money flows back to the drilling regions. Experts attribute this to the high prevalence of corruption at the top level of the administration. An additional factor is that ownership of any land-holdings where oil is found is automatically assigned to the national authorities under the Land Use Act of 1978. Communities or private owners are not normally compensated.

SANCTION MECHANISMS: To ensure that all parties abide by the agreed rules, instruments must be introduced at every level of ocean governance, i.e. on the local, regional and global levels, with which misconduct can actually be sanctioned. This provides a means of enforcing compliance with usage rights, for example. Sanctions can actually be a highly effective instrument of governance, as is demonstrated by the surveillance flights that are used in certain sea areas to spot incidents of oil pollution. Under the terms of the International Convention for the Prevention of Pollution from Ships (MARPOL), since the beginning of the 1980s, seven sea regions worldwide have been defined as Special Areas (protected areas) in which the discharge of oil from ships is prohibited. In several of these Special Areas, such as the Mediterranean, the North Sea and the Baltic Sea, surveillance flights have been carried out for many years. Since patches of oil pollution can be identified very effectively by aerial photography with special cameras, ships whose crews have cleaned their tanks at sea or jettisoned oil can swiftly be caught. Because perpetrators of illegal pollution within Special Areas can be pursued by means of criminal law, the flights have a deterrent effect: the number of illegal discharges has dropped substantially.

These general criteria for good ocean governance represent the ideal state of affairs. The first step towards comprehensive sustainable ocean governance is therefore to appraise the different levels with a view to determining how far they do or do not meet these criteria. For now, the one certainty is that there are many points where further improvement is essential.

3.13 > According to the MARPOL agreement ships' masters are forbidden to drain oil residues into the water in Special Areas like the North Sea. In the German Bight the coastguard uses planes and boats to hunt down illegal oil polluters.

Conclusion

The ideal of good marine policy

The protection and sustainable use of the ocean are, first and foremost, a political task. Each aspect must be enshrined in both international conventions and national laws, and followed through with measures to ensure compliance. "Good ocean governance" of this kind is difficult because a host of different institutions are responsible for the ocean and its protection; furthermore, the sea is subdivided into individual zones. For instance, UNCLOS contains the categories of territorial sea, which is part of a coastal state's sovereign territory; the exclusive economic zone in which a coastal state alone has the right to exploit resources and fish stocks; and the high seas, which are open to all countries for use with certain restrictions. This zoning is fundamentally in conflict with comprehensive sustainable governance of the ocean. Fish stocks move across vast areas, toxic substances are washed across national borders by the sea currents, and phenomena like ocean acidification and ocean warming pose a threat to all sea areas in equal measure.

The fact that different institutions are responsible for different types and sectors of sea use is an additional complication for sustainable governance. At the highest political level, several different United Nations institutions are dealing concurrently with different aspects of the ocean. For instance, the International Maritime Organization (IMO) lays down the rules for international commercial shipping, and the International Seabed Authority (ISA) exclusively administers the mineral resources located in high-seas areas. In addition to these, there are major UN bodies whose tasks only partially comprise particular marine aspects.

On the regional level, too, the sectoral view of the ocean currently predominates. Today almost 600 agreements are in existence which have been adopted by multiple states and which regulate particular uses in a delimited region. This large number notwithstanding, there are very few positive examples of really effective regional ocean governance.

In other cases, marine protection fails due to poor cohesion among the states. One example is the Abidjan Convention, which governs the African Atlantic coast between Mauritania and South Africa and entered into force in 1984. Due in no small part to civil wars in Côte d'Ivoire, Liberia and Sierra Leone as well as a lack of technical equipment and funds, little progress has been made towards marine protection objectives since the convention came into force. For a few years, however, the member states have been endeavouring to revitalize marine protection.

Despite the many obstacles, there are certainly examples of functioning ocean governance: for instance, port state control (PSC) was introduced in order to verify compliance with certain UN conventions. This allows a country's port authorities to detain a ship in harbour if a ship's master commits any breach of international regulations. Today, disputes between two states can often be resolved successfully in an international arena. Countries can take their cases to the International Court of Justice (ICJ) of the United Nations or to the International Tribunal for the Law of the Sea (ITLOS). Many cases revolve around violations of marine borders. However, even if a country is sentenced by ITLOS, it can refuse to accept the judgement. In that case, all that usually remains as a last resort is to exert additional pressure through diplomatic channels. For this reason, experts in the law of the sea view the ICJ and ITLOS as an international regulatory apparatus with significant weaknesses.

4 Hope for the oceans

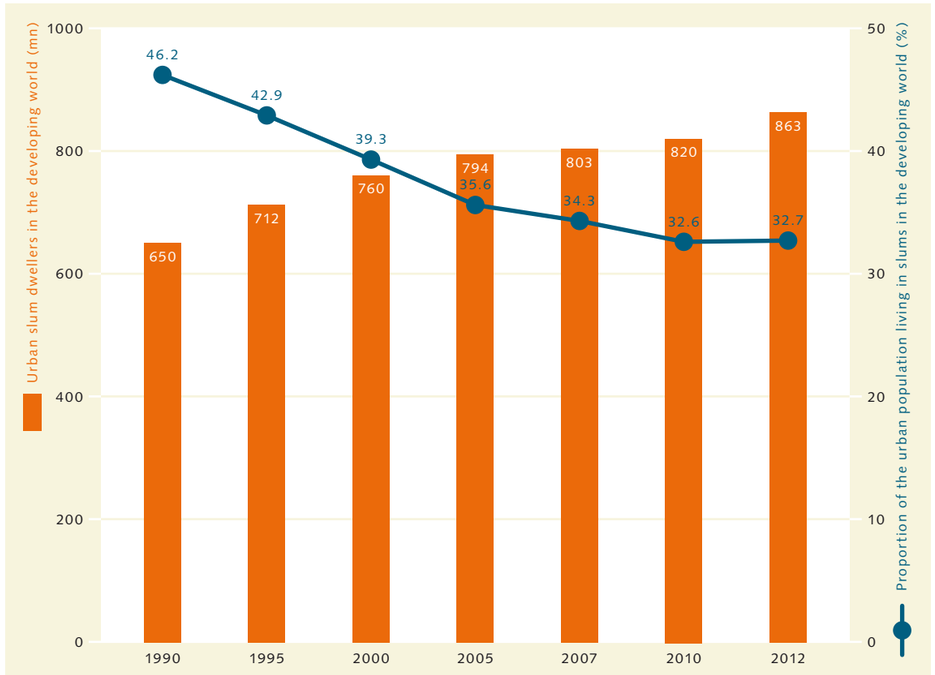
> The extent of the pollution and destruction of marine habitats is daunting. However, there are already numerous examples showing how marine conservation and the sustainable use of marine resources can be achieved – not only through international agreements but also through measures adopted at the local level. It is also encouraging that the United Nations has declared marine conservation to be one of the major development goals for the future.

Roadmap towards a sustainable future?

> Comprehensive and sustainable use of our natural resources is one of the major challenges for the future. The United Nations is therefore currently developing an agenda with 17 Sustainable Development Goals (SDGs) as a roadmap to 2030. One of these goals is sustainable use of marine resources. However, it is individual countries' commitment that will determine whether the world comes close to achieving this ideal.

Social justice – a key goal

Living conditions around the world still vary considerably. Many people live in extreme poverty, suffer hunger and have no access to education or social progress. Recognizing the major problems affecting social development in many parts of the world, the United Nations adopted the Millennium Declaration in September 2000 as the basis for the establishment of eight major development goals. Known as the Millennium Development Goals (MDGs), their purpose was to help achieve significant improvements in social conditions in the developing countries by 2015. Several of the MDGs have been reached; many have been partially met. MDG 4, for example, aims to reduce child mortality by two-thirds by 2015 compared with 1990, when annual mortality among the under-fives stood at 12.7 million. Since then, the figure has fallen to six million despite a growing world population. The United Nations sees this as a landmark victory in its campaign to further reduce child mortality.

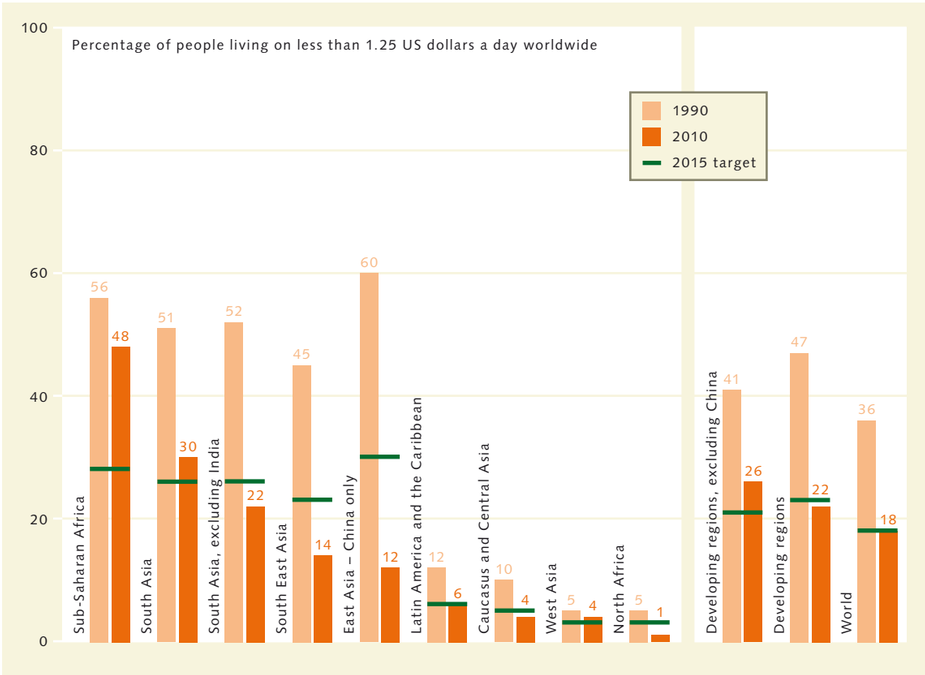


4.1 > Modest progress has been achieved on reducing the number of slum dwellers worldwide. Although the proportion of the urban population living in slums declined from 46.2 per cent in 1990 to 32.7 per cent in 2012, the absolute number of slum dwellers increased over the same period, from 650 million to 863 million, as a result of population growth.

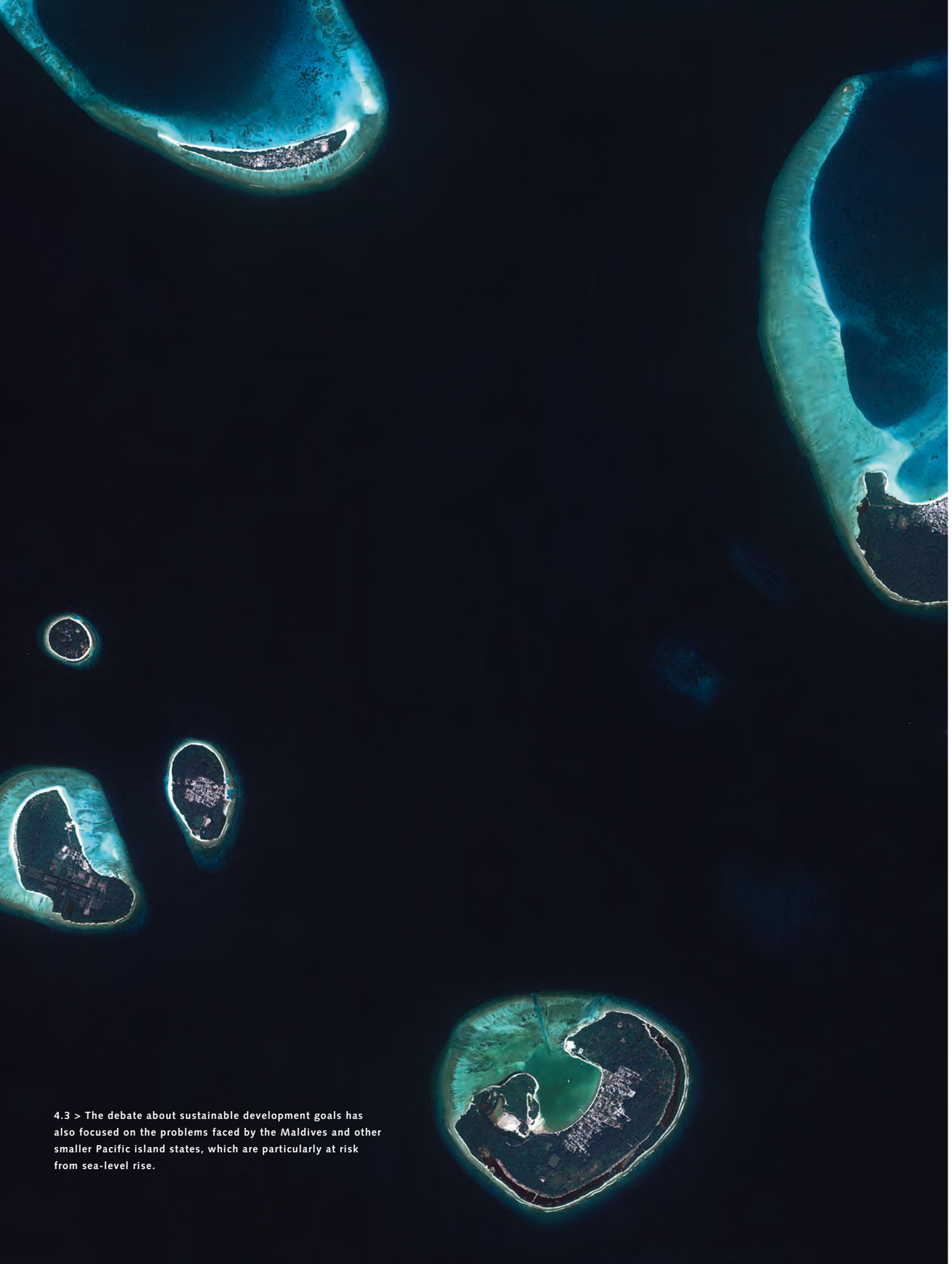
Despite these glimmers of hope, there has been frequent criticism of the MDGs in recent years. Viewed in terms of the classic three-pillar model of sustainability, the MDGs' unilateral focus on social aspects is identified as an obvious shortcoming. The environmental dimension features only once, namely in MDG 7, and there is no mention of marine resources at all. The critics also point out that the MDGs fail, by and large, to address governance aspects and that they apply only to the developing countries.

A universal global sustainable development agenda?

At an MDG summit in 2010, it was therefore agreed that a new agenda should be defined for the period beyond 2015 to 2030. The future goals should be universal: in other words, they should apply to developing, emerging and developed countries alike and should take account of all the dimensions of sustainability. Crucially, it was recognized in this context that living conditions cannot be improved if the environmental dimension is neglected and humankind's natural life support systems continue to be destroyed. The new post-2015 agenda should therefore also take account of the outcomes of the United Nations Conference on Sustainable Development (**Rio+20**) held in Rio de Janeiro in 2012, exactly 20 years after the UN Conference on Environment and Development (Earth Summit) took place in the same city. The Rio+20 outcome document deals with the social dimension, such as poverty eradication, but also calls for a green economy, as well as measures to combat environmental problems, e.g. land degradation, desertification and climate change. In order to elaborate the new post-2015 sustainable development agenda, an Open Working Group (OWG) was established in 2012 under the auspices of the United Nations; this format was chosen in order to involve a range of stakeholders in the deliberations.



4.2 > Several MDGs were reached by 2015. They include the goal of halving the number of people living on less than 1.25 US dollars a day worldwide. However, in sub-Saharan Africa, almost half the population still lives in extreme poverty, with only a very small decrease since 1990. China, by contrast, has achieved an 80 per cent reduction in the number of people living in poverty.



4.3 > The debate about sustainable development goals has also focused on the problems faced by the Maldives and other smaller Pacific island states, which are particularly at risk from sea-level rise.

Open to suggestions

In contrast to many other processes conducted under the auspices of the United Nations, the Open Working Group – as the name suggests – was intended to be inclusive and accessible to a broad public. An Internet portal was established, enabling interest groups, businesses and individuals to submit position papers and well-reasoned proposals on new goals. The scientific community and other experts were invited to share their experience on various aspects of sustainability and feed it into the process.

As a rule, every UN member state has the right to send a representative to the various United Nations committees and bodies. To ensure that every representative from almost 200 countries has a chance to have a say, the time available for individual statements is reduced to a minimum. In order to ensure that the work on the SDGs progressed in a constructive, efficient and focused manner, it was therefore agreed that in the OWG, the inputs would be streamlined, with one representative speaking on behalf of a constituency of three countries, such as the Germany/France/Switzerland trio. The constituencies' spokespersons – generally diplomats or senior officials from the member states' Foreign or Environment Ministries – rotated on a regular basis. The duration of the Open Working Group's sessions was also reduced substantially, as the aim was to submit a comprehensive proposal on the new sustainable development agenda in the shortest possible time. In order to access the knowledge of the scientific community and other civil society groups, the OWG invited experts to New York to provide brief inputs and statements on various aspects of sustainability. The aim was to consult independent scientists who were able to provide an overview of current research in their particular discipline. Directly involving external experts from civil society was an unusual move for the United Nations: generally, it is only the member countries' own designated representatives who appear before UN bodies, doing so once they have been duly briefed by policy advisors or external experts.

This consultation process involving experts and national representatives lasted eight months and also focused on the marine environment.

In spring 2014, the OWG finally published its report. In it, the OWG proposes 17 Sustainable Development Goals (SDGs) and 169 targets to be reached by 2030. This makes the list of SDGs far more detailed than the old MDG agenda with its eight Millennium Development Goals and 21 targets. As the first step, the United Nations General Assembly approved the Open Working Group's proposal in autumn 2014. In the following months, a United Nations committee held further negotiations in order to develop the SDGs in more detail and resolve the issue of financing.

Accolades from on high

In July 2015, the list of SDGs was presented at the Third International Conference on Financing for Development (FfD) in Addis Ababa. The Conference brought together high-level political representatives, including Heads of State and Government and Ministers of Finance, Foreign Affairs and Development Cooperation, to discuss how much money the international community will provide for sustainable development in the developing countries.

In the run-up to the conference, the developed countries had pledged to promote actions in support of sustainable production and consumption patterns and activities to counter the threats of climate change with contributions amounting to 100 billion US dollars from 2020 onwards. At the meeting, however, none of the countries was willing to commit definitely to payments. It thus remains unclear at present where the funds are to come from in future. At least the delegates were able to agree that projects to combat poverty or hunger must not be seen in isolation from climate action. Future development initiatives must pursue both objectives simultaneously.

A further outcome of the conference is that Germany, the United Kingdom, the Netherlands and the USA will launch an initiative by which the developing countries will be assisted in reforming their tax systems such that resources are released to fund the SDGs. Critics have noted that this approach reduces the struggle for greater sustainability to the nation-state level instead of tackling the challenges through international commitments.

The SDGs – a new 2030 global sustainable development agenda

The United Nations Open Working Group has defined 17 goals to guide the international community towards sustainable living conditions and a green economy over the next 15 years. For each of these goals, various targets have been defined, with 169 targets in total. Only the targets relating to Goal 14 are set out below. SDGs 14a, 14b and 14c are not goals per se, but describe the means and measures by which sustainable development is to be achieved in various areas.

Goal 1: End poverty in all its forms everywhere

Goal 2: End hunger, achieve food security and improved nutrition and promote sustainable agriculture

Goal 3: Ensure healthy lives and promote well-being for all at all ages

Goal 4: Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all

Goal 5: Achieve gender equality and empower all women and girls

Goal 6: Ensure availability and sustainable management of water and sanitation for all

Goal 7: Ensure access to affordable, reliable, sustainable and modern energy for all

Goal 8: Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all

Goal 9: Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation

Goal 10: Reduce inequality within and among countries

Goal 11: Make cities and human settlements inclusive, safe, resilient and sustainable

Goal 12: Ensure sustainable consumption and production patterns

Goal 13: Take urgent action to combat climate change and its impacts

Goal 14: Conserve and sustainably use the oceans, seas and marine resources for sustainable development

14.1: **By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution**

14.2: **By 2020, sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, including by strengthening their resilience, and take action for their restoration in order to achieve healthy and productive oceans**

14.3: **Minimize and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels**

14.4: **By 2020, effectively regulate harvesting and end overfishing, illegal, unreported and unregulated fishing and destructive fishing practices and implement science-based management plans, in order to restore fish stocks in the shortest time feasible, at least to levels that can produce maximum sustainable yield as determined by their biological characteristics**

14.5: **By 2020, conserve at least 10 per cent of coastal and marine areas, consistent with national and international law and based on the best available scientific information**

14.6: **By 2020, prohibit certain forms of fisheries subsidies which contribute to overcapacity and overfishing, eliminate subsidies that contribute to illegal, unreported and unregulated fishing and refrain from introducing new such subsidies, recognizing that appropriate and effective special and differential treatment for developing and least developed countries should be an integral part of the World Trade Organization fisheries subsidies negotiation**

14.7: **By 2030, increase the economic benefits to small island developing States and least developed countries from the sustainable use of marine resources, including through sustainable management of fisheries, aquaculture and tourism**

14a: **Increase scientific knowledge, develop research capacity and transfer marine technology, taking into account the Intergovernmental Oceanographic Commission Criteria and Guidelines on the Transfer of Marine Technology, in order to improve ocean health and to enhance the contribution of marine biodiversity to the development of developing countries, in particular small island developing States and least developed countries**

14b: **Provide access for small-scale artisanal fishers to marine resources and markets**

14c: **Ensure the full implementation of international law, as reflected in the United Nations Convention on the Law of the Sea for States parties thereto, including, where applicable, existing regional and international regimes for the conservation and sustainable use of oceans and their resources by their parties**

Goal 15: Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss

Goal 16: Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels

Goal 17: Strengthen the means of implementation and revitalize the global partnership for sustainable development

4.4 > Communities in the Democratic Republic of the Congo learn how to protect themselves using mosquito nets. Malaria is a frequent cause of poverty because persons with the disease are no longer able to work.

Meeting in New York in September 2015, the United Nations General Assembly – the UN's chief deliberative, policymaking and representative organ – formally approved the draft SDGs. This means that there now is, for the first time, a framework for action towards comprehensive, sustainable global development. A noteworthy positive aspect is that following adoption of the SDGs some 2000 initiatives have started their work around the world to carry out diverse projects in support of the SDGs at regional level. It remains to be hoped that this impetus can be maintained in future. For it is still unclear after the General Assembly how the SDGs are to be financed in the period to 2030.

The SDGs: the critics' view

In spring 2015, the International Council for Science (ICSU) already published a paper on the Open Working Group's set of SDGs, in which it reviews the 169 targets for the Sustainable Development Goals from a science perspective and considers how well developed each target is. It concludes that out of 169 targets, 29 per cent are well developed, 54 per cent could be strengthened by being more specific, and 17 per cent require significant work.

Among other criticisms, the ICSU argues that as they stand, the SDGs fall short of the high standards initially set by the OWG itself. It notes that all the targets should meet the SMART criteria – a concept borrowed from business and project management, which states that goals can only be achieved if they fulfil the following five criteria: they must be specific, measurable, attainable (and ambitious), relevant, and time-bound. The ICSU therefore made the following criticisms:

- Some goals are insufficiently specific. For example, Target 14.7 calls for the sustainable use of marine resources by small island developing States. However, it is not specified what the term "marine resources" encompasses. In this case, it should be made clear that marine mining or, indeed, energy generation should be developed in a sustainable manner.
- Some Sustainable Development Goals are not quantified, i.e. they lack measurable indicators, meaning that some countries may fail to pursue the goals with sufficient commitment. Target 14.1, for example, merely calls for "marine pollution of all kinds" to be significantly reduced. However, this is an ideal rather than a specific goal. It would be more useful to specify target figures, e.g. reduce existing marine pollution of all kinds by 30 per cent, as this is a clear and achievable goal.
- There are major differences in the urgency with which the various goals must be addressed. For example, developing countries which at present have to make considerable efforts to combat hunger and malnutrition (SDG 2) will have less capacity to invest in promoting sustainable tourism (one of the targets for SDG 8) than a developed country. Prioritization of certain goals from the outset would therefore have been useful.
- The number of SDGs (17) and targets (169) is unrealistically high, and it is already foreseeable that only a proportion of the SDGs will be reached with the funding available. The number of MDGs was smaller and clear priorities were set, which was essential to making progress in the first place, the ICSU notes.
- No deadlines have been set for reaching some of the SDGs; one example is Target 14.3, which merely states that the impacts of ocean acidification are to be minimized and addressed.
- Possible conflicts between some of the goals have not been adequately considered. For example, Goal 2 calls for an end to hunger in the world; in line with Target 2.3, agricultural productivity will have to double by 2030 in order to achieve this goal. However, as this will require the use of large quantities of artificial fertilizer, there is a risk that this will cause even more nutrient pollution of rivers and coastal waters, creating a possible conflict with Target 14.1, which calls among other things for pollution, including nutrient pollution, of coastal waters to be significantly reduced.

So why are there so many points of criticism, and why are the SMART criteria not always met? Experts say that this is because the United Nations negotiations are first and foremost a political process: the aim is to find a formula that is acceptable to all countries. Even with criteria such as SMART, the wording is often vague. The reality is that consensus is essential in the United Nations, for resolutions such as the SDG agenda can only be implemented if they are adopted unanimously by the General Assembly. Very few UN bodies operate a system of majority voting.

Since the SDG process commenced, the representatives of the Open Working Group have responded publicly to criticism. They point out that the purpose of their work was to overcome the limitations of the Millennium Development Goals and to devise a sustainable development agenda that is as comprehensive as possible and covers the environment, economic and social dimensions in equal measure. And, they say, a political process always involves weighing up which goals should ultimately be pursued, and with which degree of intensity. The OWG accepts the criticism that not all the Goals will be reached by 2030. However, it is keen to ensure, in every case, the continuation of projects that have progressed successfully thanks to the MDGs.

Looking for the right benchmark

Notwithstanding all the criticism, it must be kept in mind that the SDG process is far from complete. Quite the contrary: the detailed work is only just beginning. Defining goals and targets was merely the first step. The second consists of defining indicators – benchmarks – to measure, in future, whether and to what extent progress towards the goals is being made. The list of indicators should be ready by spring 2016.

Fifteen years ago, the **United Nations Statistics Division** developed 60 indicators to measure progress towards the Millennium Development Goals. As not all the MDGs can be measured equally, the indicators were assessed according to their feasibility, suitability and relevance. Very much like the ratings used to rank countries'

4.5 > Critics are calling for the threat to the deep sea from marine mining and oil production to be defined more precisely in the SDGs. At Miami Beach (above) and elsewhere, there have already been numerous protests against the sell-off of the seabed.

creditworthiness, the system – which is likely to be adopted for the SDGs – awarded a score from AAA to CCC for these three criteria. This can be illustrated with reference to Goal 1: Eradicate extreme poverty and hunger. One of the indicators for MDG 1 was "proportion of population below the national poverty line, disaggregated by sex and age group". This parameter can be measured very accurately because most countries maintain detailed statistical data. This indicator was therefore awarded an AAA ranking.

Furthermore, all those MDG indicators which have proved their worth will be retained for the SDGs. In addition, the UN Statistics Division is currently developing new or better indicators, again drawing on external expertise. The Division published a list of 338 proposed indicators in early 2015.

4.6 > Melting of continental glaciers, seen here in Greenland, is one of the greatest threats posed by global warming. Combating climate change is one of the most ambitious and challenging goals on the SDG agenda.

The complexities of data collection

Experience with the MDGs has shown that data collection and statistical analysis of indicators cost a great deal of time and money. The success of the SDG agenda therefore depends, not least, on adequate funding being available for this purpose. Given that there are 17 SDGs and 169 targets, the effort involved is several orders of magnitude greater than for the MDGs. In mid 2015, the Open Working Group signalled that collecting the requisite data for 169 targets and the same number of indicators and reporting the figures to the United Nations was likely to be unmanageable for many countries, especially those whose monitoring systems and/or statistical offices are underresourced or (almost) non-existent. According to the experts, the upper limit is 100 harmonized global SDG indicators in order to be sure that all countries submit their data to the UN Statistics Division within a reasonable timeframe. Timely submission of national data is essential to allow conclusions to be drawn as to whether countries are on track to achieve their goals.

During the MDG era, analysing the data was often difficult as the figures were submitted with several years' delay. As the MDG process continued, however, many developing countries built up their statistical capacities and the situation improved. The OWG assumes that 100 indicators are manageable. However, it remains to be seen whether 169 targets can be captured adequately with just 100 indicators.

In practice, it will also become apparent that not all targets are equally relevant to all countries. For example, not every landlocked country needs to take measures to combat eutrophication of coastal waters if it has no rivers that wash nutrients into the sea. Malaria is another example: this particular problem does not affect the Northern European countries, so for them, providing data on this particular indicator is unlikely to be onerous. This reduces the amount of data that countries need to provide, as some targets may not be relevant.

A small set of indicators for everything?

One topic of discussion at present is whether a small set of comprehensive indicators can be used to measure progress towards several targets. This is quite conceivable, as many of the goals are linked. One example is the sustainable use of marine resources – a major goal which comprises many targets, such as conservation of fish stocks, reduction of nutrient loads, etc. Theoretically, all these aspects could be captured by a single indicator such as the Ocean Health Index (OHI), which assigns a single score to describe the condition of ocean regions or, indeed, the global ocean. The technical term for an indicator which covers a range of aspects is a "composite indicator". A country's gross national income can also be considered a composite indicator.

Although the OHI was discussed as a possible SDG indicator, it has now been rejected: the OHI is an extremely complex indicator, consisting of 10 categories which are used to evaluate the condition of marine ecosystems. There were also concerns about the weighting of the categories, because the OHI simply adds them together and calculates simple mean scores on that basis. Critics argue that as a result, poor results in one category can simply be cancelled out by good results in another; the OHI implicitly adheres to a weak concept of sustainability, in that natural capital that has been destroyed can simply be substituted to an almost unlimited extent by other forms of natural capital. Nonetheless, efforts are currently under way to de-termine to what extent the SDG indicators can be merged in order to reduce the total number. Identifying thematic overlaps can certainly help. Combating poverty (SDG 1), for example, is impossible without food security (SDG 2).

The limits to the SDG agenda

Notwithstanding all the justified criticism, many scientists consider that the Sustainable Development Goals (SDGs) build successfully on the Millennium Development Goals (MDGs). Whereas the MDGs were defined by United Nations experts and adopted by the UN General Assembly fairly quickly, the SDGs have been developed in an inclusive process lasting several years. This was essential to produce a comprehensive agenda which also places emphasis on good governance at the national level, which has an essential role to play. For example, SDG 16 calls for promotion of peaceful and inclusive societies and the provision of access to justice for all. Goals such as these touch on politically sensitive areas. They are entirely new: they were not included in the MDGs and have therefore not been captured in statistics. Developing appropriate indicators is therefore proving extremely difficult. For example, what kind of indicator can be used to measure "the percentage of population who believe decision-making at all levels is inclusive and responsive"?

Whether the SDGs genuinely contribute to a sustainable future will undoubtedly depend on the policies adopted at the national level. The SDG agenda is not legally binding. If countries fall short of their goals, there is no way of sanctioning them. Scientists emphasize, however, that the mere existence of the MDGs exerted a measure of pressure. Failure to achieve key goals thus harmed a country's international reputation. The SDGs are likely to have a similar effect, encouraging the adoption of national or regional measures to combat localized environmental problems such as nutrient pollution of water resources.

As a rule, countries give top priority to their own national problems. The question, then, is to what extent countries will in future be willing to work together to tackle global challenges such as climate change or ocean warming and acidification. In many cases, the international community has failed to get a grip on global environmental threats despite the existence of binding multilateral agreements such as the Kyoto Protocol. So it is almost impossible to predict to what extent the SDG agenda will motivate countries to take concerted action. The MDGs' strength lay primarily in their clarity: they were easy for everyone to understand. This led to a high level of public interest and awareness, with non-governmental organizations, citizens' action groups and the press in many countries casting a critical eye over whether and to what extent the MDGs were being achieved. In view of the high level of attention already focused on the SDGs, it is likely that a similar process of critical monitoring will accompany progress towards the SDGs, prompting intense public debate over the next few years. This may well exert additional public pressure on governments to show more commitment to working together on tackling global problems in the next decade and a half.

Kyoto Protocol
In order to reduce emissions of greenhouse gases such as carbon dioxide, the international community adopted the United Nations Framework Convention on Climate Change in New York in May 1992. The Convention was further elaborated in a Protocol adopted in Kyoto, Japan, in 1997, which sets internationally binding emission reduction targets for the first time. Despite these agreements, greenhouse gas emissions have increased in some developed countries and especially in the emerging economies.

Protecting the seas is possible

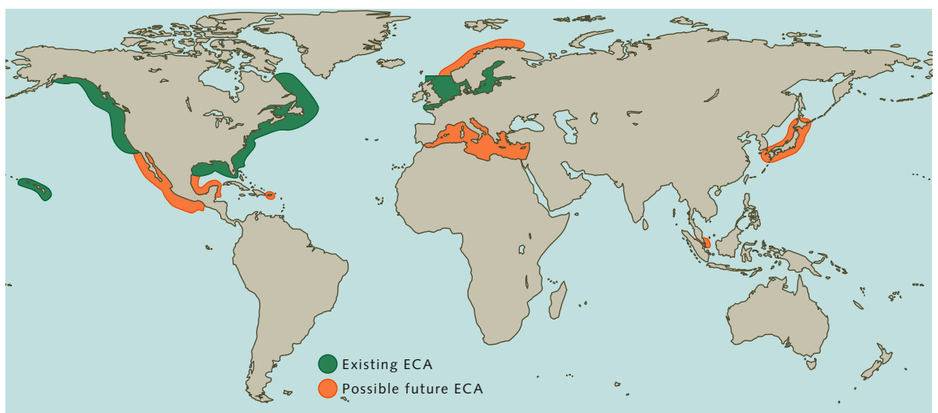
> Various agreements on the conservation of the marine environment and the sustainable use of marine resources have been implemented successfully around the world. In the process, however, it has become apparent that there is a strong preference for conservation measures that can be adopted at least cost. If more progress is to be achieved, all groups within society must play their part in demanding and taking action to save our seas.

Successes at the local level and in the international arena

Comprehensive and sustainable use of the marine environment is still a long way off: that is evident from the continuing overexploitation of fish stocks in European waters, the oil pollution in the Niger Delta and the eutrophication of the Yellow Sea off mainland China. On the other hand, there are many positive examples which prove that protecting the seas is possible – both at global and at regional or local level. The motivations for protecting the marine environment and moving towards sustainability vary considerably, as do the methods by which this is achieved. In some cases, massive public pressure has resulted in higher standards of protection or the use of improved technologies. In others, there were sound economic arguments for implementing appropriate measures. Often, a detailed cost-benefit analysis revealed that investing in sustainability was the more cost-effective option.

Cleaner shipping

In some instances, it takes time for states to reach agreement on marine protection regimes. Indeed, this is often only possible if the rules are not too stringent or the negotiating partners set long deadlines for achieving specific goals. This search for the lowest common denominator does not necessarily mean a poor compromise; it is often a crucial step in the right direction. A topical example is the reduction of harmful emissions from the burning of cheap, low-grade heavy fuel oil (HFO) in shipping. Ships running on HFO emit large quantities of sulphur oxides (SO_X), nitrogen oxides (NO_X) and particulate matter (soot) in their exhaust gases, which can cause respiratory diseases. While catalytic converters in vehicles and cleaner heating and industrial systems have done much to reduce air pollution in many ports, ships continue to emit their unfiltered exhaust gas into the atmosphere. In some dockland areas, the concentration of air pollutants reached such high levels in recent years that new waterside housing projects were put at risk. There was also pressure from the tourism industry: the growing number of cruise ships led to a deterioration in air quality in the very coastal resorts that are popular with passengers and advertise the fact that they offer clean and fresh seaside air.



4.7 > Emission Control Areas (ECAs) are sea areas in which shipping is subject to stricter emissions limits. Environmental organizations are calling for ECAs to be established in other coastal regions with a high volume of shipping traffic.

In order to improve the situation, the member states of the International Maritime Organization (IMO) agreed that the emission limit values (caps) had to be reduced. Limit values are set under an IMO agreement, the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78). MARPOL contains several annexes specifying in detail which particular types of pollution are prohibited. The new caps on exhaust gas are set out in Annex VI to the Convention. Among other things, the sulphur content in heavy fuel oil is to be reduced worldwide. Until 2012, a maximum sulphur content of 4.5 per cent was permitted. This was lowered to 3.5 per cent in 2012, and will be reduced to a mandatory 0.5 per cent globally, although this will not happen until 2020.

In addition, Annex VI to the Convention defines various sea areas – known as Emission Control Areas (ECAs) – in which more stringent regulations apply.

Emission Control Areas have been established for some of the busiest shipping routes where the adoption of special mandatory measures for emissions from ships is required to prevent, reduce and control coastal air pollution. These special areas currently include the English Channel, the North Sea and the Baltic Sea, where there is a high volume of shipping traffic, and the waters off the coast of the US and Canada. A 1.5 per cent maximum sulphur content in fuel applied in the Baltic from 2006 and in the North Sea from 2007, and this was lowered to 1.0 per cent in 2010 and then to 0.1 per cent from January 2015.

Noxious emissions from shipping can be abated if vessels switch to much more expensive diesel, or are fitted with marine exhaust gas cleaning systems. Both options increase the costs to the shipping companies, which vigorously opposed tighter emission limit values for many years. Environmental organizations therefore view the decision to allow vessels to continue to burn heavy fuel oil with a very high sulphur content (3.5 per cent) in international waters until 2020 as a concession to the shipping companies. The fact that these limit values were adopted at all, despite opposition from the shipping industry, is due to the cost-benefit ratio. Ports and coastal towns benefit from a thriving shipping industry, transshipment and cruise tourism as these sectors generate income. However, the tourism industry and local communities are vocal in their opposition to air pollution, with mounting public pressure against emissions from shipping in recent years, especially in the ECAs. Cruise ships and larger commercial vessels are therefore required to switch to diesel when lying at anchor in the ECAs. The more stringent IMO rules are intended to reduce air pollution from passing ships in future as well. The benefits, then, are better air quality in the ECAs and less conflict between the shipping industry, on the one hand, and tourism and ports/coastal communities, on the other. Environmental organizations are now calling for other sea areas, such as the Mediterranean, to be designated as ECAs.

The MARPOL Convention is an international treaty, and compliance is therefore mandatory under international law. States which have acceded to the Convention

4.8 > Exhaust gases from shipping are a problem in many ports, such as Hamburg (above). Under IMO rules, these exhaust gases will contain lower levels of pollutants in future. Black smoke cannot be avoided altogether, however: it is emitted in short bursts from ships' revving engines during docking.

are thus permitted to verify a vessel's compliance with these more stringent emissions limits and, indeed, with MARPOL's other provisions while the vessel is in port. Under this system of Port State Control (PSC), authorities may also levy fines for non-compliance, which must be paid immediately in cash. Vessels or their flag state may also incur penalty points under an international points system. The penalty point system enables persistently non-compliant vessels to be flagged up in the international databases, with the result that their masters must expect the checks to be repeated in other ports en route.

The end of commercial whaling

The commercial whaling moratorium is another example of a successful international agreement. Adopted by the members of the International Whaling Commission (IWC) in 1982 following the dramatic decline of many whale populations, the moratorium entered into force in 1986, spelling the end for the commercial hunting of the great whales. Progress towards this goal was fraught with difficulty, however.

The IWC was established in 1948 by 14 member countries, all of which were engaged in commercial whaling on a relatively large scale. At that time, the IWC's main purpose was to set whaling quotas, which were then allocated to the individual member countries. As the quotas were not based on whale numbers but were simply intended to ensure that the profits from whaling were shared as fairly as possible, whales were hunted relentlessly. In 1961/1962 alone – a record season – some 66 000 whales were killed worldwide. Studies undertaken in the Southern Ocean in the early 1960s revealed the severely depleted status of the whale populations for the first time.

Catch limits, e.g. for blue whales and humpback whales, were agreed within the IWC framework on various occasions, but several of the whaling nations opposed the restrictions and whaling continued. As whale populations steadily declined, the first of the major UN environmental conferences – the United Nations Conference on the Human Environment (UNCHE) in 1972 – called for a moratorium on commercial whaling, initially for 10 years. Nevertheless, whaling continued, whereupon various environmental organizations began to protest more vigorously against whaling – in some cases with headline-grabbing campaigns in which activists on inflatable boats attempted to disrupt whaling operations at sea. In many countries, there was a shift in public mood, with growing opposition to whaling. In 1982, Seychelles abandoned commercial whaling and proposed a moratorium for the first time.

Until that point, the IWC had mainly consisted of countries which were engaged in or supported whaling. However, the IWC is an international organization and is open to any country in the world, and now it began to attract more countries which were opposed to whaling. In 1986, anti-whaling nations formed the majority in the IWC for the first time, enabling the moratorium to be adopted. Iceland, Japan, Norway and the Soviet Union lodged objections to the moratorium and continued their whaling operations. Russia ceased whaling at the end of the Cold War, although it formally maintains its objection to the present day. Iceland and Norway have also maintained their objections but unlike Russia, they have continued their commercial whaling operations, setting their own catch quotas each year. Japan finally withdrew its objection but its whaling programme also continues, based on Japan's invoking of a clause in the International Convention for the Regulation of Whaling – the IWC's key document – which permits whaling for purposes of scientific research. The IWC also allows some indigenous communities which have traditionally engaged in subsistence whaling to continue this practice for livelihood purposes.

Despite all these limitations, the moratorium is widely regarded as a success. In 1982, prior to the moratorium, more than 13 000 whales were killed. Now the figure is around 2000 whales killed each year. Iceland and Norway mainly hunt northern minke whales *(Balaenoptera acutorostrata)*. Iceland also catches fin whales *(Balaenoptera physalus)*, which are still relatively abundant. Blue whales and other species described by the IWC as rare species requiring special protection are not hunted. Another success is that the moratorium has made it possible to establish the Southern Ocean Whale Sanctuary in the area surrounding Antarctica, which is an important region for whales. Even today, there is an ongoing dispute within the IWC as to whether the ban on whaling should be eased. Japan in particular is attempting to win other member states' support for its interests. However, there is no need for concern about a possible softening of the moratorium at present.

Moratorium
A moratorium is an agreement on the suspension of an activity, by which states undertake not to exercise their use rights or enforce claims to payments. A moratorium generally remains in force for a limited period. Various states or communities such as the Greenlandic Inuit, which depend on subsistence whaling, are exempt from the whaling moratorium. The International Whaling Commission (IWC) discusses such exemptions at its regular meetings.

4.9 > For the men of the Chukchi people in northeast Russia, hunting gray whales is an age-old tradition. They use the meat to feed themselves and, above all, their sled dogs.

Why does conservation fail?

These and other examples show that with clear rules, rigorous implementation and stringent controls, it is possible to protect the marine environment. But this raises the question why relatively few of the agreements have been successful so far. The Kyoto Protocol, for example, shows how difficult it is to make climate protection a global obligation. The Kyoto Protocol was the first international agreement to establish an absolute and legally binding limitation on greenhouse gas emissions. Under the Protocol, the developed countries pledged to achieve specific greenhouse gas emissions reductions. The Protocol contains detailed regu-lations on emissions of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and several other greenhouse gases. Although carbon dioxide is not the most potent greenhouse gas, it is released in very large quantities through the burning of natural gas, oil and coal, and is therefore of particular significance. For the first Kyoto commitment period (2008 to 2012), the European Union, for example, pledged to cut its greenhouse gas emissions by 8 per cent compared with baseline year 1990. This target was met.

The problem is that not all developed countries acceded to the Kyoto Protocol. The US, for example – the world's second largest emitter of carbon dioxide – did not sign the Protocol. Making matters worse, no limits were agreed for the developing countries and transition economies because their per capita greenhouse gas emissions are much lower than those of the developed countries. However, with their populations each exceeding one bil-

4.10 > China is one of the world's largest producers and consumers of coal. Coking plants are particularly densely concentrated in Linfen in the southwest of Shanxi Province. The US Blacksmith Institute rated the city among the world's most polluted places in both 2006 and 2007.

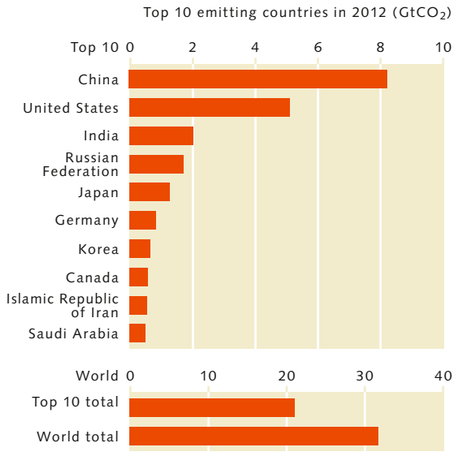
lion, both China and India emit vast quantities of greenhouse gases. Today, China is the world's largest carbon dioxide emitter and is thus a major contributor to the greenhouse effect. For the sake of the climate, it therefore needs to cut its emissions as a matter of urgency. However, it is also important to consider that a large percentage of China's carbon dioxide emissions come from heavy industry, which manufactures products for the European and US markets. In that sense, China's carbon dioxide emissions cannot be viewed in isolation from the importing countries. This shows that effective climate action is, without doubt, a global responsibility.

Climate protection – a lonely pursuit

At the end of the first commitment period, the parties to the Kyoto Protocol met again in order to agree new climate targets for the second commitment period (2013 to 2020). Although the international community agreed fresh targets, this time, it was not only the US but other countries too that rejected the new commitments. Japan, Canada, New Zealand and Russia are no longer participating in the second commitment period. Reduction commitments were adopted by the European Union and its member states, Australia, Belarus, Iceland, Kazakhstan, Liechtenstein, Monaco, Norway, Switzerland and Ukraine. Together, however, these countries account for just 15 per cent of global emissions. As a result, greenhouse gas emissions have continued to rise. The Kyoto Protocol is therefore not generally regarded as a success. The future allocation of greenhouse gas reductions remains a contentious issue, as is the question of how the developing countries and transition economies, especially China and India, can be persuaded to cut their carbon dioxide emissions.

Short-term thinking vs. climate action

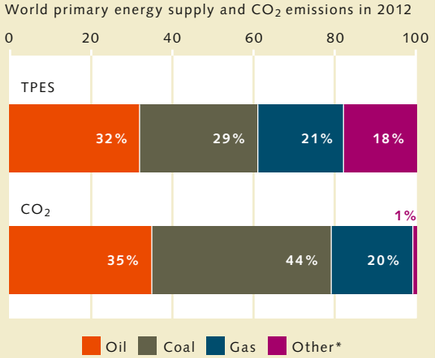
So what are the reasons for the Kyoto Protocol's and other environmental agreements' lack of success? From the economists' perspective, the answer is clear: national implementation of agreements or regulations ultimately depends



4.11 > Two-thirds of the world's carbon dioxide emissions are produced by just 10 countries. China and the US are by far the largest emitters.

on the extent to which the benefits outweigh the costs for the country concerned. If a target can be reached at minimal cost, national measures are more likely to be adopted. One example is the new waste ordinance in Oahu, one of the islands in the Hawaiian Archipelago. Since 1 July 2015, the ordinance has banned businesses from handing out plastic bags to their customers. The authorities' aim is to reduce the amount of plastic waste, much of which ends up as marine litter. The plastic bag ban does not cost Hawaii very much at all, as alternatives such as paper bags and biodegradable plastics have existed for some time. The benefits, however, are substantial, as the ban is helping to keep Hawaii's beaches litter-free and promotes its image as an unspoilt, near-natural tourist destination.

Dispensing with fossil fuels is difficult, however, as almost all the national economies are dependent on them. Crude oil is used to produce fuels to power vehicles; natural gas and coal are needed for electricity generation and heating. The transition to alternative technologies such as photovoltaics and wind power is complex and requires major upfront investment, the costs of which seem extremely high compared with other energy sources. However, conventional cost-benefit calculations often



4.12 > Compared with other fossil fuels, the burning of coal releases particularly large amounts of carbon dioxide. Although more oil than coal is burned worldwide, it emits less carbon dioxide. Renewable energy technologies such as photovoltaics, hydro and wind power, but also nuclear power plants produce next to no carbon dioxide emissions during their operation. The above figures do not take into account energy consumption and carbon dioxide emissions from uranium mining, the manufacture of wind turbines and photovoltaic systems and the construction of hydropower plants.

Fish stock
A stock is defined as a self-sustaining population of a fish species within a specific sea area. As a rule, the various stocks of a species are so geographically separate that one stock's individuals do not mix with another's, even though they belong to the same species. In a fisheries context, this means that a species is very rarely totally depleted; generally, this applies only to a specific stock.

ignore the external costs. Energy generation is a case in point: at present, only the costs of the feedstocks used to produce electricity or heating tend to be considered. Coal, a fossil energy source, thus appears to be a cheap fuel. For that reason, many countries use vast amounts of it. However, this cost-benefit analysis does not factor in the external costs associated with the greenhouse gas emissions produced in the burning of coal. No price is put on the droughts, storms, ocean acidification and sea-level rise caused or exacerbated by climate change.

As the gains from the avoidance of external costs are not considered, many countries continue to rely on fossil fuels. In the transition economies and developing countries, such as China and India, where industrial production is booming, soaring energy demand is therefore met primarily by cheap coal. Many other countries also shy away from the costly transition to low-carbon technology, with the result that global carbon dioxide emissions are still rising. Instead of investing in alternative technologies, private-sector energy suppliers and industry keep costs down for the present by utilizing cheap fossil fuels. Society will have to pay the price in future, in the form of high consequential costs.

Free riders obstruct environmental protection

In a situation like this, the free rider problem occurs. Free-riding countries are those which make little or no contribution to climate protection. They leave it to other states to invest in climate change mitigation and to switch to renewable energies. Without making any contribution themselves, they profit from others' efforts and investment. This in turn deters those countries which would otherwise be willing to invest in protecting the climate and the environment. Due to the free riders, however, they have little incentive to intensify their commitment.

As a consequence, some countries are demanding that the top 10 carbon dioxide emitters – including China, the US, India, Russia, Japan and Germany, which together produce two-thirds of global carbon dioxide emissions – massively reduce their CO_2 emissions before they themselves take action. China and India counter with the argument that the leading industrialized countries should take action on the climate first of all. The result is that very little progress is made. On the other hand, China – unlike the US – is now attempting to make more intensive use of renewable energy sources, primarily hydro, wind and solar.

China has therefore greatly expanded its wind energy sector in recent years. By the end of 2014, China's installed wind power capacity was almost equivalent to that of all the European wind farms combined. The total capacity of US wind farms, by contrast, is only half this amount. However, in some cases, this massive expansion of renewable energies in China is causing major problems. China's hydropower projects, such as the Three Gorges Dam, are an example. The damming of the Yangtze River has destroyed numerous towns, villages and natural habitats, and this damage is irreversible.

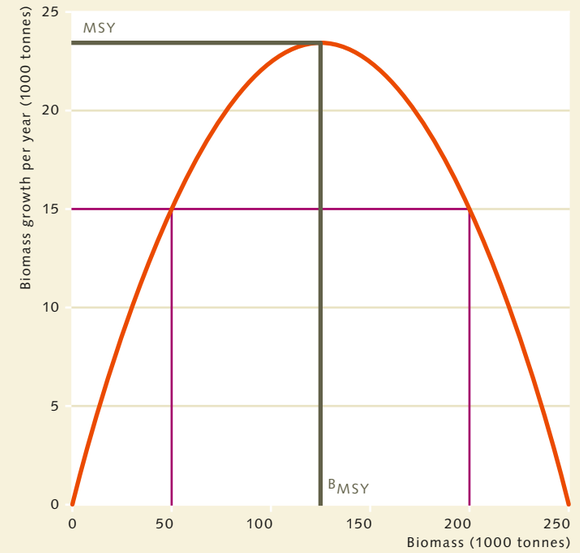
Some progress nonetheless

Despite national self-interests, environmental protection and a sustainable economy are within reach at the international level, as a multitude of examples show. For the marine environment, the European Union's new Common Fisheries Policy (CFP) is particularly noteworthy; it aims to end the overexploitation of European fish stocks. For many years, the EU's fishing fleet was far too large, but there was vehement opposition to any restriction on fishing from politicians keen not to lose votes, especially in structurally weak regions. Accordingly, the annual Total Allowable Catches (TACs) set by EU fisheries ministers for the various species were often far higher than recommended by scientists, resulting in the progressive overexploitation of many stocks. Today, stocks are mostly made up of smaller and juvenile fish, which are often thrown back into the sea because they are below the prescribed minimum size. This practice of discarding fish has steadily worsened the problem of overfishing in recent years.

In view of the permanent massive overexploitation of many of the EU's fish stocks, a change of policy was finally agreed. The new CFP entered into force in 2014. Its aim is to regulate fishing in a way which allows fish stocks to recover, enabling them to be fished at an optimal level in future. Fishery scientists see this as a milestone in the move towards the sustainable exploitation of Europe's fish stocks. Although discussions on how the new fisheries policy should be implemented day-to-day are still ongoing, a start has been made. From now on, fishing in the EU will be based on maximum sustainable yield (MSY). The MSY is the maximum catch that can be taken from a species' stock over an indefinite period without jeopardizing that stock's productivity.

Fishing based on MSY not only gives fish stocks a chance to recover. It also offers a range of economic benefits. If stocks are allowed to grow, this increases fisheries' catch potential. Future catches will consist of larger fish, which fetch higher market prices per kilo, and discards will decrease. If stocks consist of larger fish, it takes far less time to catch a tonne of fish, reducing fishing

Why fishing at MSY levels delivers more



4.13

The maximum sustainable yield (MSY) is the maximum catch that can be taken from a species' stock over an indefinite period without jeopardizing that stock's productivity. The maximum sustainable yield (MSY) is achieved at a certain level of biomass (B_{MSY}). This differs in size from fish stock to fish stock. At B_{MSY} the annual production of new biomass is at its maximum – firstly because the fish grow particularly well and increase their weight, and secondly because more eggs and larvae survive to develop into fish.

Above or below B_{MSY}, the stock is less productive. At about 200 000 tonnes biomass, for example, the stock provides only 15 000 tonnes of new biomass per year. This is because there are more fish in the stock to compete for food, and they each put on less weight. Also, more eggs and juvenile fish are cannibalized. A stock of only 50 000 tonnes biomass experiences a similar level of biomass growth. Although this smaller stock contains fewer spawners, the total achieved from the increase in weight of the individual fish (as a result of reduced competition for food) and the biomass of the offspring (which have a greater chance of survival within a smaller stock) is the same as for a large stock.

It is interesting that sustainable fishing is also possible with larger or smaller sized stocks than the B_{MSY}, but the annual fish yield is lower.

effort and cutting fuel and wage costs. Ultimately, higher profit margins and rates of return can be achieved – and that means additional revenue for the fishing industry.

Accurately estimating fish stocks

For fishing to be based on MSY, however, it is essential to know how many fish there are in the sea. The challenge is that the size of a stock naturally fluctuates from year to year. Key environmental parameters determining the number of juveniles produced include water temperature, salinity and oxygen concentration. The food supply also determines how well the fish grow. Today, it is recognized that even regular climatic fluctuations influence the development of fish stocks. So it is not enough to set a specific allowable catch once and for all. On the contrary, fishery scientists must reassess the stock every year to enable them to make catch recommendations for the coming fishing season; in other words, they must determine the total allowable catch, in tonnes, at a level that does not exceed the MSY.

4.14 > Pilot projects are now under way to test the installation of on-board cameras as a means of monitoring catches.

In order to estimate stock size, scientists utilize catch data from fishermen, as well as the findings from catch samples collected during research expeditions. Using mathematical models, they then calculate the recommended maximum annual catch.

This process is made more difficult, however, by the fact that a variety of methods exist for calculating the MSY, sometimes resulting in discrepancies in the figures. Fishing in Australia and the US is now based on MSY, but their management regimes differ nonetheless. The International Council for the Exploration of the Sea (ICES) is currently advising the EU bodies on the introduction of appropriate calculation methods.

Doing battle against discards

In order to protect and ensure the optimal use of fish stocks in future, the new CFP also envisages various measures to reduce discards. They include the introduction of selective fishing gear specifically designed to catch only the target species. However, even the use of improved fishing gear does not always avoid fish of different species ending up in the same net. Specialists call this a mixed fishery. In cod fisheries, for example, haddock and whiting are often caught as bycatch. This has caused problems because fishermen were only permitted to land the species for which they had been allocated a quota – generally cod. All the other fish and marine fauna caught as bycatch were dumped overboard. Most of the discards were already dead when they went back into the water. In future, fishermen engaged in mixed fishing should acquire quotas for all species likely to end up in their nets. As soon as a quota is exhausted, fishing must cease in order to avoid overexploitation of the species – even if the quotas for the other species have not yet been exhausted. Discussions are currently under way to determine how the EU can best monitor the discard ban. One option is to install sealed CCTV cameras to monitor activity on deck. According to experts, the widespread use of this or other solutions in routine fishing operations is simply a matter of time. From their perspective, EU fisheries policy reform was the most important factor, and this has been achieved with the new CFP.

Centralism gives way to regional responsibility

The new CFP has introduced another change as well: the individual fishing regions will now have a greater say. Previously, all the rules were agreed centrally in Brussels and applied equally to all the EU waters. However, fisheries can vary considerably according to species and region, making it almost impossible to apply all the rules to all the various regions. Some rules were found to be unworkable, so new rules were adopted without amending or repealing the first. The outcome, over time, was an overly complex and sometimes contradictory EU fishing regime. Many of the EU rules were therefore viewed by fishermen themselves as excessive or impractical. Indeed, some of them were ignored altogether.

The new CFP now provides for greater involvement of fishermen in fisheries management and decision-making. For example, Member States can delegate decision-making power to the regional level and give responsibility to the regional bodies where the fisheries directors of the seaboard states are based, such as the Baltic Sea Fisheries Forum (BALTFISH) – the regional body providing a platform for discussion of fisheries issues in the Baltic Sea. These bodies can then draft management plans that are appropriate for their specific region, which will then be approved by the EU's Agriculture and Fisheries Council. The regional bodies will hold regular consultations with a second tier, namely the Regional Advisory Councils. Up to two-thirds of the members of the RACs are experts from the fisheries sector, with experts from other interest groups, such as nature conservation organizations and trade unions, comprising the remaining one-third.

With its regionalization of fisheries policy, the EU is to some extent following the example of the US, where fishing has been based on MSY for some years and regional fisheries management regimes are in place in various coastal regions and are the responsibility of five regional fishery bodies. In 2013, for the first time, all five regional fishery bodies in the US set their total allowable catches precisely according to the recommendations made by fishery scientists, based on MSY – a move which fishery scientists hail as a success. In addition to the US and the EU, Australia has based its fishing activity on MSY for some time. Here too, fishermen are involved in fishery management at the local level.

Fishing vs. marine conservation?

A further challenge for the EU at present is to bring fisheries management into line with the Marine Strategy Framework Directive (MSFD) adopted in 2008. The general aim of the MSFD is to achieve or maintain good environmental status in the marine environment. There is thus an obligation not only to ensure that fisheries are exploited at sustainable levels, but also to minimize impacts on seabed habitats. Bottom trawling can degrade these habitats even if the fishery in question is sustainable in terms of its impact on fish stocks. According to the MSFD, fishing should in future be managed in such a way that EU sea areas which merit a specific protection regime are no longer fished at all, or are fished less intensively. In the EU, some scientists are currently mapping the seabed and gathering information on which types of organism occur in various seabed habitats, such as mussel beds, seagrass beds and diverse types of sediment. Maps are also being produced to show the level of intensity of fishing in the various areas, so that in future, it will be possible to assess more accurately which specific areas are particularly sensitive and should perhaps be excluded from fishing activities that impact on the seabed.

Various uses in a limited space

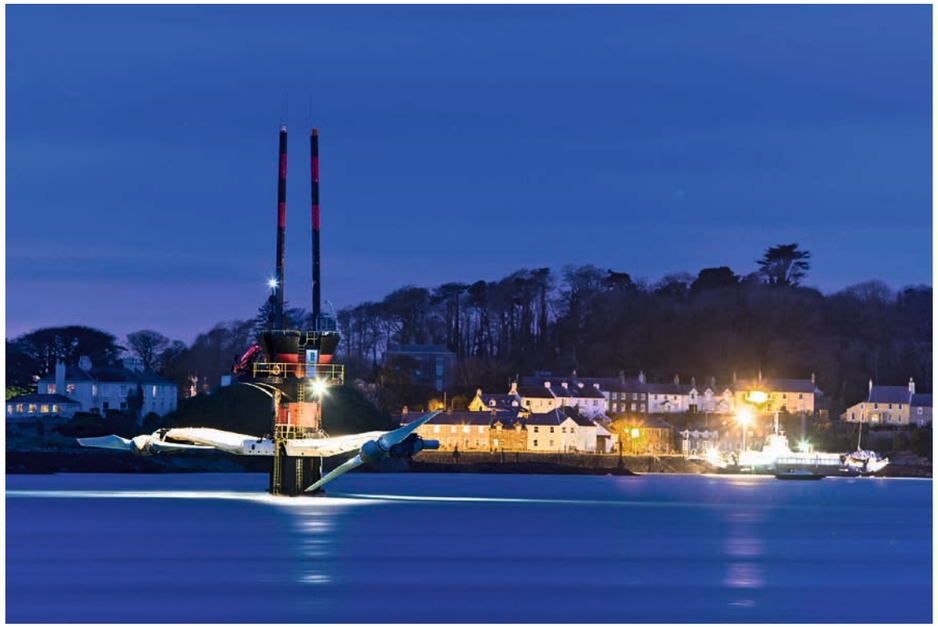
If the marine environment is to be protected more effectively, based on the sustainable management of its resources, there must, in future, be better coordination between its conservation and use. Marine spatial planning (MSP) is an important tool in achieving this goal. MSP is a means of coordinating the various coastal and marine interests. Economic activities in the marine environment, e.g. fishing, offshore wind farm construction, dredging for marine aggregates (i.e. gravel and sand), shipping and oil production, must be balanced against other uses, such as leisure and recreation and, not least, conservation.

MSP was first developed in the 1980s as a means of resolving conflicts of interest over the conservation and use of the Great Barrier Reef along the east coast of Australia. Experts now take the view that a marine spatial plan should always be based on an ecosystem approach; in other words, a sea area should be managed in a way which avoids negative impacts on marine habitats and the provision of ecosystem services. Ultimately, marine spatial planning should prevent the proliferation of uses which has caused major pollution of coastal waters and environmental problems in many regions of the world in the past. The prerequisite for a successful MSP is that all stakeholder groups and the local community are involved in the planning process.

Offshore wind powers spatial planning

Since the start of the new millennium, interest in marine spatial planning has noticeably increased. Contributory factors are the increase in shipping and the trend towards more offshore extraction of mineral resources such as natural gas and oil in many sea areas. In Europe, particularly in the United Kingdom and later also in Germany, the strong expansion of offshore wind power was also a driving force behind the introduction of MSP. The question of how to reconcile wind power expansion with shipping and safety along maritime transport routes was the main focus of attention here. The authorities therefore demanded detailed analyses of the potential risks posed by wind turbines, for example in the event of a damaged vessel drifting at sea. Attention also focused intensively on the extent to which large-scale wind farms affect the flyways of migratory birds, and biological assessments were conducted to answer this question. Denmark and the Netherlands, for their part, were keen to assess to what extent offshore construction would jeopardize the status of the Wadden Sea as a UNESCO Natural World Heritage site.

The expansion of offshore energy worldwide seems set to continue, and from a climate perspective, this is a welcome trend. However, this form of energy generation will inevitably clash with aspects of marine conservation and use, not only in Europe. Even during construction, there is potential for conflict. The use of heavy piledriving machinery to ram the foundations of wind turbines into the seabed triggers powerful sound waves which are now known to cause hearing impairment in marine mammals. Although the use of mitigation devices, such as air bubble curtains, to reduce underwater noise is now being trialled, it seems likely that in future, wind farm construction will in some cases have to take the behaviour of marine mammals into account, for example by halting construction to allow whale mothers and calves to pass. And once a wind farm is established, fishing – a key sector of the economy in many coastal states – becomes impossible in that area, so alternatives must be identified. All these aspects must be considered in marine spatial planning in future.



4.15 > The SeaGen tidal energy convertor in Strangford Lough in Northern Ireland is a 1.2 megawatts device whose output is comparable to that of a wind turbine. SeaGen is unusual in that it uses rotors to produce power, whereas the common method of extracting tidal energy utilizes turbines installed in a barrage wall.

The perfect MSP

At first, each country implemented MSPs as it saw fit, with little sign of any harmonized spatial planning. MSP experts from UNESCO's Intergovernmental Oceanographic Commission (IOC) therefore published guidelines on marine spatial planning in 2009. They set out a step-by-step approach for ideal marine spatial planning in line with ecosystem-based management. As the authors themselves emphasize, these guidelines are a general tool which can be applied at international, regional and local level. According to the guidelines, marine spatial planning should consist of the following 10 steps:

- Identifying need and establishing authority;
- Obtaining financial support;
- Organizing the process through pre-planning;
- Organizing stakeholder participation;
- Defining and analysing existing conditions;
- Defining and analysing future conditions;
- Preparing and approving the spatial management plan;
- Implementing and enforcing the spatial management plan;
- Monitoring and evaluating performance;
- Adapting the marine spatial management process.

The authors point out that MSP is a long-term process which must be continuously tailored to changing conditions; this involves further consultation between planning authorities and the various stakeholder groups. Identifying possible alternative sea use scenarios is also important, as is setting specific planning objectives at the outset, which should be measurable. Comprehensive marine spatial planning has many advantages, according to the authors. One is that it allows stakeholders' common interests to be identified. For example, an offshore wind farm can provide a refuge for certain species of fish, particularly juveniles, as no fishing takes place in this area. Tourist excursions to wind farm sites are another possible option. In sea areas where natural reefs have been destroyed by fishing, the bases of wind turbines can act as artificial reefs for

4.16 > Marine spatial planning can also help to mitigate conflicts between wind turbines and the flyways of migratory birds.

The ecosystem approach
The ecosystem approach is a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way. Instead of applying a species-by-species approach, it focuses on the dynamic relationships within and among species and between species and their natural environment.

Offshore energy – creating space for green power plants at sea

Climate change will radically alter conditions in the marine environment in future. Atmospheric warming will be accompanied by a rise in the temperature of seawater. Scientists attribute the mass die-off of tropical coral reefs to rising water temperatures. Furthermore, a large amount of the carbon dioxide emitted into the atmosphere from the burning of coal, oil and natural gas dissolves in seawater and, put simply, forms carbonic acid. The likely impacts of this ocean acidification are still impossible to predict. The melting of the continental glaciers in Greenland and the Antarctic has the potential to cause sea levels to rise by several metres over the coming centuries. This would spell disaster for people living in low-lying coastal regions. These impacts of climate change can only be avoided if humankind switches from fossil fuels to renewable energies as soon as possible.

The marine environment can facilitate this process. The wind across the sea, the waves and the currents contain vast amounts of kinetic energy, i.e. the energy of motion, which can be converted into electricity. The key renewable marine energies are:

- wind energy;
- wave energy;
- tidal energy;
- ocean current energy;
- energy derived from temperature differences at various ocean depths (ocean thermal energy conversion – OTEC);
- energy derived from the different salt content of freshwater and saltwater (osmotic power).

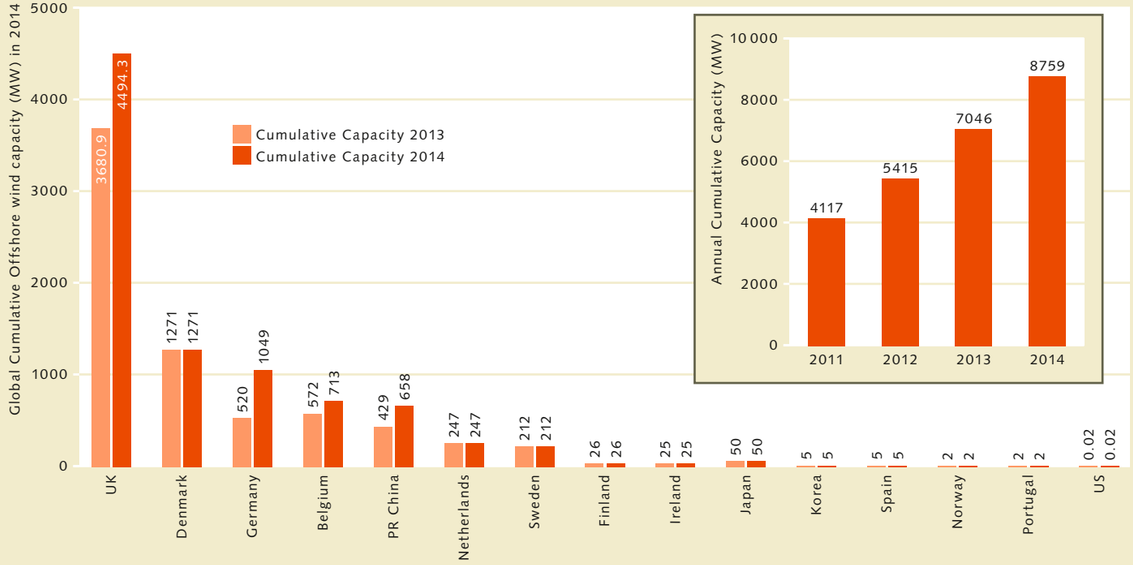
Electricity currently accounts for around 18 per cent of the world's total energy consumption. Renewable marine energies have the potential to meet a substantial share of the world's electricity needs. Wind energy appears to be the most promising: experts estimate that offshore wind power alone could in future supply around 5000 terawatt-hours (TWh) of electricity a year worldwide – approximately a quarter of the world's current annual electricity consumption of about 20 000 terawatt-hours (1 terawatt-hour = 1 trillion watts). However, it is essential to differentiate between the technical potential of an energy technology and its sustainable potential. The technical potential includes all the plant locations which are theoretically feasible. The sustainable potential looks at environmental factors, such as the damage that the construction of foundations for offshore wind turbines causes to seabed habitats. The sustainable potential is accordingly lower than the technical potential.

Offshore wind power is the marine energy currently at the most advanced stage of development. In 2014, the many thousands of wind turbines installed worldwide had a total **nominal capacity** of 8795 megawatts. An average offshore wind turbine produces 2 to 4 megawatts – enough to supply around 5000 households with electricity. Nominal capacity is the maximum output generated by a wind turbine in optimum wind conditions. At present, the total capacity of offshore installations is low compared with onshore wind farms. For example, the wind turbines installed onshore in the German state of Lower Saxony alone have a total capacity of around 8300 megawatts. Nonetheless, the expansion of offshore wind energy has gained considerable momentum in recent years. In 2011, annual global cumulative offshore wind capacity was just 4117 megawatts. Installed capacity has thus more than doubled between 2011 and 2014.

Europe in particular has greatly expanded its offshore wind power sector in recent years. At the end of 2014, 2488 offshore wind turbines were installed in European waters, making a cumulative total of 8045 megawatts. Europe thus produces some 90 per cent of the world's offshore wind-generated electricity. The United Kingdom leads the field, with around 4500 megawatts of installed capacity in its coastal waters. There are several reasons why the UK has surged ahead: the expansion of offshore wind began early on; as an island, the UK has a large EEZ; and, thirdly, turbines were erected in shallow waters fairly near to the coast. In Germany, by contrast, there were massive protests against offshore wind expansion near the coast. The tourism industry was concerned that holiday-makers would be disturbed by the sight of large wind farms on the horizon. Conservationists cautioned against siting wind turbines close to the Wadden Sea, a UNESCO World Heritage site and an important resting area for millions of migratory birds. Most of Germany's wind farms are therefore located in deeper waters some distance offshore, creating greater technical complexity. Delays also occurred in Germany because the routes selected for the power lines connecting the wind farms to the onshore grid ran through sea areas contaminated with unexploded ordnance from the Second World War, which first had to be cleared.

China has emerged as the global leader in the expansion of onshore wind energy, taking only a few years to achieve this status. Experts are therefore predicting that China will also invest heavily in the expansion of offshore wind. In the US, by contrast, only a small number of offshore pilot projects have been launched to date.

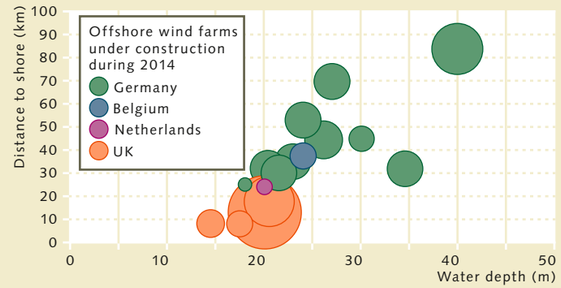
There is growing interest in offshore wind energy in Japan as well. Here, however, there is a very steep descent to the deep ocean floor, with very little shallow water around the Japanese islands compared with Europe. Japan therefore favours floating wind farms which stand upright in the water and are anchored to the seabed with steel cables. A number of these installations already exist around the world. This is viewed as a mature technology, although the great depths involved make it more expensive than conventional wind farms.



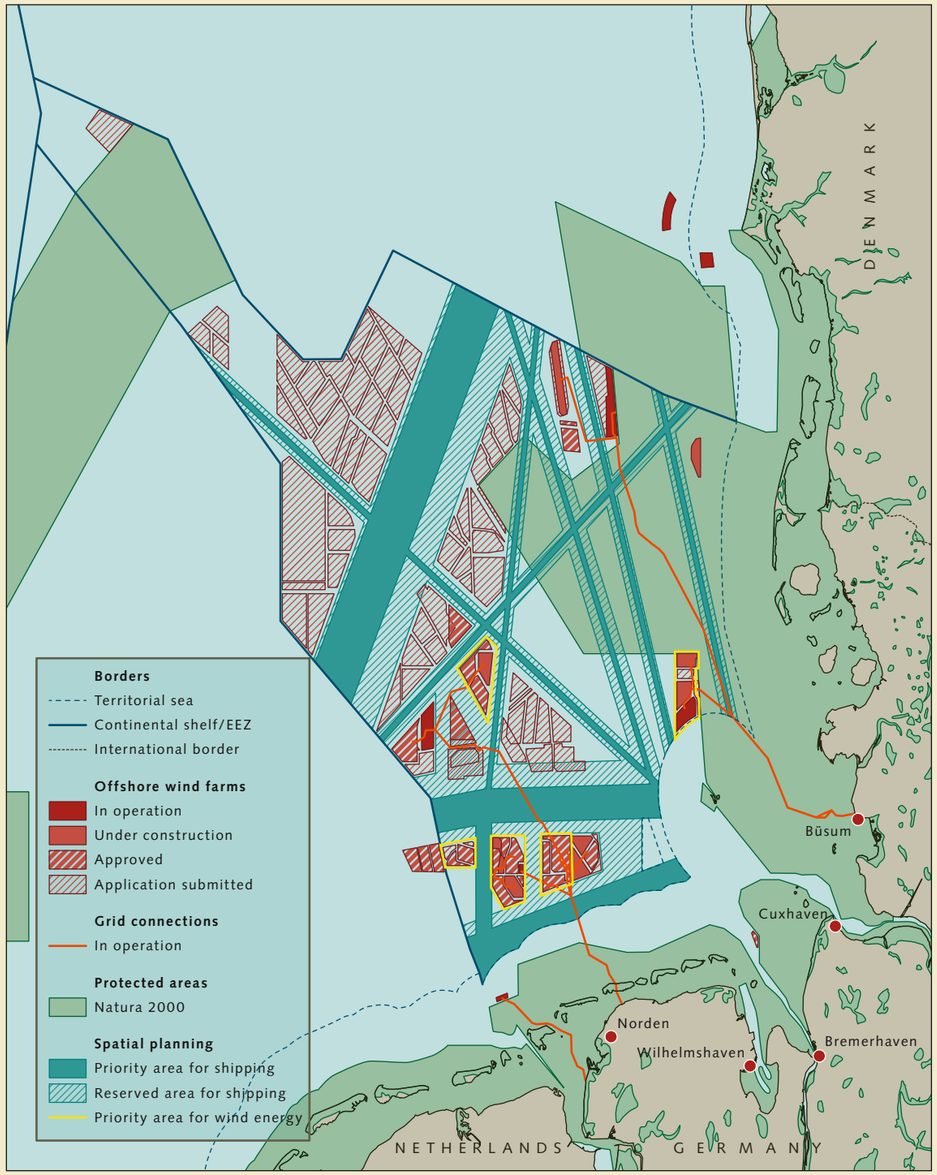
4.17 > The United Kingdom currently leads the field in the expansion of offshore wind power. In Germany, many offshore projects are now nearing completion, so it is likely to move up to second place over the next few years. The current dynamic momentum in this market is evident from the fact that global cumulative offshore wind capacity has doubled in just a few years.

Compared with wind, the other offshore marine energy technologies are still in their infancy. Although a number of wave, ocean current and osmotic power plants already exist around the world, many of them are prototypes. Industrial production on a large scale, comparable with wind energy, is still a long way off. Ocean thermal energy conversion (OTEC) is the least advanced of these technologies. In the 1990s, several small-scale prototypes were built in Hawaii, but a larger fully operational system has yet to be constructed.

Tidal power plants have been an established technology for decades, but rely on dams and barrages for the installation of large turbines, making their construction extremely complex. For that reason, very few of these plants exist worldwide. A notable example of a tidal power plant is the La Rance Barrage near the town of Saint-Malo in France, which has been in operation since 1966.



4.18 > Other countries, different building regulations: in Germany, the construction of wind farms near the coast is banned, whereas the United Kingdom has built many wind farms in much shallower waters directly off the coast. This is possible, not least, due to the lack of extensive tidal sand and mud flats in the UK.



4.19 > Spatial plans for the German EEZ, which have existed since 2009, specify which uses are permitted, and in which areas. As shown above, wind farms may only be constructed outside Natura 2000 sites some distance away from shipping lanes.

colonization by marine organisms that require a hard substrate. And lastly, various types of offshore energy can be combined; for example, ocean current energy installations can be mounted on the bases of wind turbines, thus making better use of the available space in the sea area concerned.

Mandatory marine spatial planning

In a number of countries, MSP is now regulatory and enforceable under national law; examples are Belgium, China, Germany, the United Kingdom and the US. In the European Union, a directive requiring Member States to harmonize their maritime spatial planning entered into force in 2014. The aim, among other things, is to avoid conflicts at the borders between EEZs. For example, it should be possible, in future, to avoid a situation in which a marine protected area on one side of the border lies directly adjacent to an area where a neighbouring state plans to dredge for sand and gravel.

With its Federal Spatial Planning Act (Raumordnungsgesetz), Germany is a good example of how multiple interests can be reconciled through regulation. Under the longstanding procedure stipulated by this Act, areas are designated for specific types of land use, such as economic development, nature conservation, and recreation. The areas are then marked on a detailed land use map. This spatial planning model has now been extended to the EEZ and marine spatial plans have been produced.

Initially, the driving force was offshore wind energy as part of the German government's massive expansion of renewable energies at the start of the new millennium. Unlike shipping and fishing, wind turbines are a static, not a mobile form of use, occupying space in the sea area concerned for at least 25 years. They can thus be regarded as permanent structures. As a wind farm with 100 turbines easily covers an area of 30 to 40 square kilometres, their space requirement is considerable. Risk analyses were therefore conducted to assess to what extent wind farms posed a shipping hazard. As a result, wind farm exclusion zones were identified to prevent collisions from occurring, as were priority areas for wind energy.

Protected areas in the EEZ

The spatial plans for Germany's exclusive economic zone (EEZ) entered into force in 2009. Among other things, they show power line routes and marine dredging areas (aggregates), as well as marine protected areas, i.e. Natura 2000 sites. Under various EU directives, each Member State is required to designate Natura 2000 sites, which together form an EU-wide network of nature protection areas, the aim being to combat the fragmentation of Europe's protected habitats so that rare fauna and flora can regain access to their original areas of distribution. The Natura 2000 sites include some coastal and offshore areas in the Member States. According to experts, Germany has set an example in its spatial planning by designating all the Natura 2000 sites in its EEZ as zero-use zones, whereas it is customary to allow economic uses to continue in Natura 2000 sites provided that assessments are conducted to show that this does not adversely affect their conservation function. Around 30 per cent of Germany's EEZ in the North Sea and 50 per cent of the EEZ in the Baltic are thus protected.

There are some criticisms, however. Before the spatial plans entered into force in 2009, various companies had submitted applications to construct wind farms. For one project, operators were granted a licence prior to 2009. However, this would now be located in a Natura 2000 site. But because approval had already been granted, the project can still go ahead. Spatial plans in Germany are usually revised every seven years or so, but critics are keen to amend the spatial plan now, so that the longstanding permission for the construction of the wind farm in the protected area is withdrawn.

British pragmatism

As Germany has a federal structure and thus consists of a number of constituent states, harmonizing marine conservation requires considerable administrative effort. The spatial plans adopted at federal, i.e. national, level only apply to the EEZ. The states of Lower Saxony (North Sea), Schleswig-Holstein (North Sea/Baltic Sea) and Mecklen-

4.20 > Laying of undersea cables, which is carried out by large specialist vessels such as *Team Oman*, must also be considered in marine spatial planning.

burg-Western Pomerania (Baltic Sea) are responsible for protecting the territorial sea. This increases the need for coordination, as the national authorities must first reach agreement with their counterparts in the individual states. Negotiations were required, for example, to identify where the power lines for the wind farms should cross the border between the EEZ and the territorial sea.

A more pragmatic approach to marine spatial planning is adopted in the United Kingdom, which does not have a federal structure and where responsibility for marine spatial planning is not divided among a number of public authorities. In the UK, the Marine and Coastal Access Act 2009 created the Marine Management Organisation (MMO), which has been responsible for marine spatial planning in England and Wales since it was set up. The MMO is an executive non-departmental public body, sponsored by the Department for Environment, Food and Rural Affairs (Defra). The MMO is responsible for various marine activities, including monitoring of fisheries management plans, dealing with marine pollution emergencies such as oil spills or other environmental disasters, and, of course, developing the MSP. The granting of licences or leases for the economic exploitation of marine assets, on the other hand, is a matter for the Crown Estate, the public body which manages the Crown's property portfolio.

The MMO has split England's inshore and offshore waters into 11 marine plan areas, for which planning processes are currently being conducted. For the East marine plan areas, for example, consultations lasting until early 2015 were held with a large number of stakeholder groups and interested parties, including representatives of:

- aquaculture;
- defence and national security;
- energy production and infrastructure development;
- fisheries;
- local communities and elected members;
- local authorities;
- marine conservation;
- marine aggregates;
- ports and shipping;
- telecommunications and cabling;
- tourism and recreation;
- wastewater treatment and disposal.

In order to involve the various stakeholder groups, the MMO offered the following opportunities for dialogue until early 2015 for the East marine plan areas alone:

- five series of stakeholder workshops attended by over 300 people;
- 400 one-to-one meetings between the MMO and representatives of various stakeholder groups and Members of Parliament;
- local liaison officers based in Lowestoft and Grimsby met with many local stakeholders and attended their meetings and events;
- 23 public **drop-in sessions** across the East attended by over 700 people;
- specific groups or fora, e.g. Local Authority elected members, Local Government Associations, conservation authorities, etc.;
- international workshops with experts from Belgium, Denmark, Germany, Netherlands, Germany, Norway and the European Commission;
- two decision-makers' workshops.

In addition, around 2000 comments and proposals from 70 different organizations were dealt with.

Based on the MSP guidance provided by UNESCO's Intergovernmental Oceanographic Commission (IOC), this aspect of the MMO's work is regarded as exemplary. The marine spatial planning process in England is still ongoing. Thus it is likely to take several years, until the implementation of the first action programmes based on MSP, before it becomes apparent whether this planning process and the intensive involvement of stakeholder groups are capable of producing successful marine spatial plans.

Help towards self-help

As is evident from the example of marine spatial planning in Belize (see Box overleaf), which involved numerous experts from various non-governmental and environmental organizations, external assistance is often required. The nature of this external support may vary, but the diverse approaches have, for some years, been subsumed under the heading "capacity building". Academic institutions take this as meaning the promotion of scientific expertise through joint projects, exchanges or training programmes involving researchers or technical staff. For development agencies, it tends to refer to the granting of microloans, enabling the unemployed in developing countries to purchase a plot of land or open a small artisanal business with a view to generating their own income.

In other cases, capacity building is the term applied to projects involving direct contact between development workers and local communities. The ultimate goal is implementation of these projects by stakeholders and local project managers, with external support being reduced to a necessary minimum. This approach does not necessarily require millions of euros in development assistance. Often, what is needed, first and foremost, are well-qualified facilitators who are able to identify solutions for the community concerned and motivate and provide training for local people.

Nowadays, many organizations are engaged in projects which focus on the sustainable management of coastal and marine habitats. In most of these regions, poverty and population growth have forced local communities to destroy their natural resource base. One example is the island of Gau, which belongs to Fiji's archipelago in the southeast Pacific. Agriculture has caused problems on Gau and neighbouring islands. Firstly, areas of rainforest were cleared some years ago to create arable land, which was used to grow food for local communities. Secondly,

MSP in Belize – not just good on paper?

In the IOC experts' view, Belize in Central America is an international model of best practice in successful marine spatial planning. Here, the marine spatial planning process, in which marine conservation was a priority, has now concluded, although the plan has yet to be approved by Parliament.

The coast of Belize is home to the world's second longest unbroken reef system, the Belize Barrier Reef, which contains a rich diversity of species, including three atolls and extensive mangrove forests. Around 40 per cent of the Belizean population of approximately 300 000 live and work in the coastal zone, many in tourism, which generates more than 10 per cent of GDP. Other revenue sources are aquaculture and fishing. Belize also has an oil and petrochemicals industry.

As in other maritime states, the Belizean coastline was under severe threat from population growth, construction and overfishing. However, the government was relatively quick to respond. It adopted the Coastal Zone Management Act in 1998 – long before MSP became a topic of discussion. A Coastal Zone Management Authority and Institute (CZMAI) was set up at the same time, although it took more than 12 years to produce the Belize Integrated Coastal Zone Management Plan, whose aim is to balance economic development and marine conservation. Various non-governmental organizations assisted the Coastal Zone Management Authority and Institute with the preparation of the management plan.

As the first step, a review of the current human uses of the marine and coastal zones was conducted, with gathering of all the available data and information on aspects such as coral reefs, manatee and turtle populations, lobster fisheries, commercial shipping and cruise tourism, popular sites for recreational activities and diving, areas of oil/petroleum leases, and much more.

Nine use zones, i.e. coastal agriculture, aquaculture, coastal development, dredging, fishing, oil exploration, marine recreation, marine transportation and conservation, were identified along the coast and offshore, and nine planning regions were established. Stakeholder consultations were then held in all the regions and included community-level group meetings. Representatives from all sectors and interests – from business to fishing and conservation – were encouraged to share their ideas and suggestions.

Based on this overview of local opinion, which was continuously updated, it was possible to develop ideas on future development, usage and conservation in the various coastal and marine regions. Using the latest modelling and planning software, three scenarios were developed in this way:

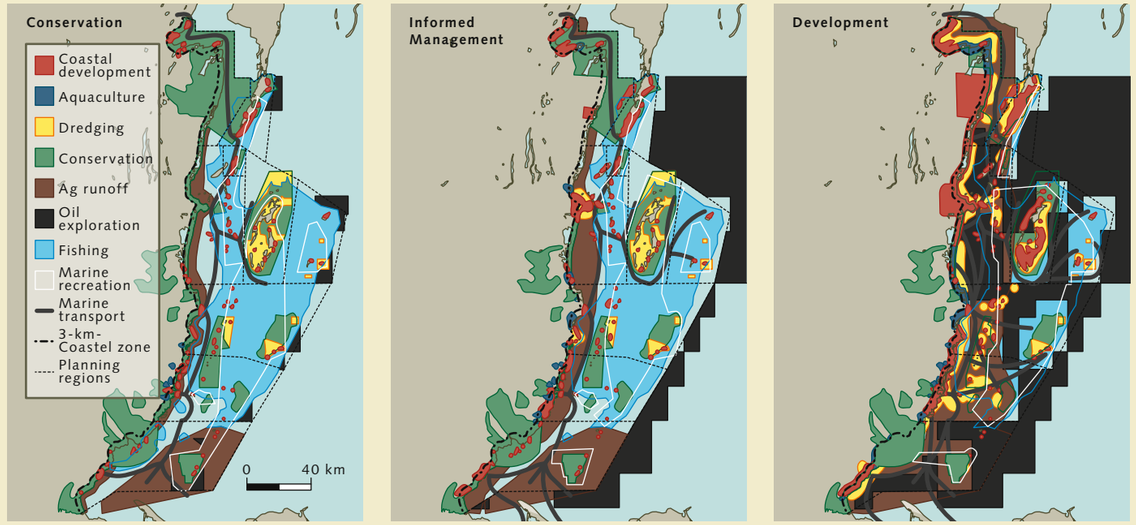
- **Conservation:** In this scenario, preservation of ecosystems and biodiversity are heavily favoured over economic development. This largely reflects the position of environmental activists.

- **Development:** This scenario generally prioritizes the interests of the extractive industry and developers, and visualizes rapid economic growth and urbanization.

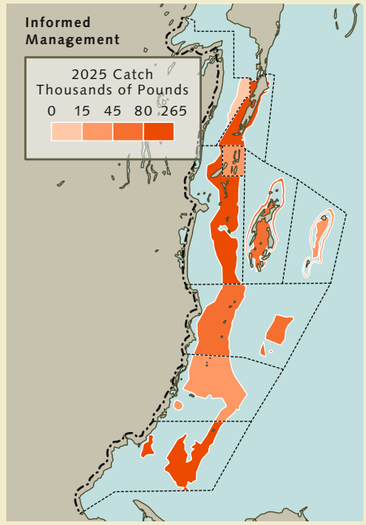
- **Informed management:** This scenario, initially regarded as a compromise or moderate scenario, envisages a cautious and sustainable approach based on planning for economic development and conservation of critical resources, minimizing impacts on coastal and marine ecosystems and maximizing benefits.

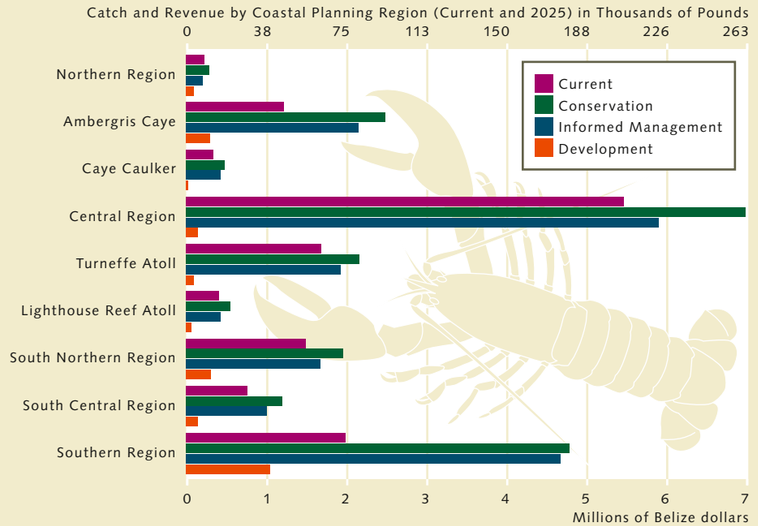
The informed management scenario was ultimately endorsed as the best option for Belize, as it represents the most sustainable future for Belize's coastal zone while ensuring more prosperity for Belizeans. All development projects and approval procedures must comply with this management plan in future. An evaluation of the plan will take place every four years. Despite this comprehensive approach to marine spatial planning, which has received international accolades, criticism has also been expressed in various quarters. Scientists point out that the impacts of climate change have not been factored into the calculations, and that technological advances and changing market prices have not been considered.

A far more serious issue is that the plan has still not entered into force. At present, Belize lacks the governmental and political structures required for its successful implementation. Otherwise, it is impossible to explain why, in 2015, the Energy Ministry announced plans to expand oil production in the immediate vicinity of the Belize Barrier Reef, a UNESCO Natural World Heritage site. This unleashed a storm of protest around the world. A final decision on the expansion of oil production has yet to be taken.



4.21 > In order to visualize possible future development, three alternative scenarios were produced as part of the marine spatial planning process in Belize. The country, which lies along Central America's Atlantic coast, opted for the informed management scenario, a strategy which allows cautious development with no adverse impacts on coastal habitats. It is clear from the above that oil production should only be permitted on the periphery of the planning regions.





4.22 > Using professional planning and modelling software, it is possible to forecast the catch and revenue for local lobster fishing in Belize in the nine planning regions in 2025. This shows that the highest values are achieved with the conservation scenario, while the development scenario produces the lowest figures.

cattle and pigs were left to roam around, damaging the best farming areas and contaminating vital water resources. The adoption of westernized lifestyles resulted in growing levels of pollution on the island. Settlements lacked a drainage system for the disposal of waste- and rainwater. And last but not least, the clearing of mangroves led to a decline of fishing and caused coastal degradation. With support from the University of the South Pacific, various solutions were developed for the districts of Gau in partnership with local communities. They include the following:

- the establishment of no-take marine areas to support the recovery of fish stocks;
- construction of a stone breakwater to protect coastlines as a partial replacement for the destroyed mangroves;
- replanting of mangroves to provide natural flood protection and act as a nursery for fish;
- planting of native hardwood to protect the villages from storms and provide a timber supply in the future;
- controls on the cutting of trees in forests;
- monitoring and prevention of wildfires;
- promotion of a smokeless stove to reduce the firewood requirement;
- improved animal husbandry, including pens for cattle and pigs;
- construction of small drainage pits;
- sorting and composting of waste;
- planting of pandanus (voivoi), which is used for making mats for sale as an income generation measure;
- planting of village taro gardens and sale of taro fruit (for flour and animal feed) as an additional income generation measure.

As the project managers emphasize, this example reaffirms the importance of building trust, involving local communities in the projects and working in partnership with them. This is the only way to identify needs and impart an understanding of sustainable resource management.

A global voice for small-scale fishing

Partnership with people is also a priority for the global research network "Too Big To Ignore" (TBTI). TBTI aims to improve economic conditions for the many millions of people around the world whose livelihoods depend on small-scale fisheries (SSF), as the debate about overexploitation of marine resources has long been dominated by industrial fishing. TBTI therefore aims to promote sustainable fishing so that over the long term, adequate incomes and livelihoods are safeguarded for fishermen.

The network currently comprises more than 60 researchers from 27 developing and developed countries and transition economies, who are initially engaged in collecting detailed data on local fishermen's living conditions. The researchers and their project partners input the data into an open-access Internet platform, known as the Information System on Small-scale Fisheries (ISSF), which also contains specialist literature on the various fishing regions in all the coastal nations. The information can be accessed by clicking on a map on the relevant webpage.

TBTI thus aims to elevate the profile of small-scale fisheries, as artisanal fishermen are still marginalized in many countries. The network will also explore how fishermen's living conditions can be improved, especially in the West African region, whose coastal waters are already overexploited to some extent as a result of industrial fishing.

The network further looks at economic relationships, such as fishermen's pay, commercial channels for the distribution of fish, and the proportion of the final price that is received by the fishermen. Possible impacts of climate change and potential strategies for adapting to future sea-level rise are also analysed.

Laying the foundations

An interesting example of capacity building at academic level is a programme run by the International Ocean Institute, which has offered an annual Ocean Governance workshop in Canada for young professionals from various disciplines from all over the world for more than 30

4.23 > Small-scale fisheries are still very important in many countries. Fishing techniques vary considerably from country to country. The photo shows traditional stilt fishermen near the town of Galle on the Sri Lankan coast.

years. The aim is to deepen young people's understanding of the ever-increasing importance of the oceans as they embark on their careers, thereby laying the foundations for participants to act as advocates for marine conservation throughout their professional lives. To date, around 600 people have participated in the workshops in Canada and many of them now hold positions in which they maintain close contacts to policy- and decision-makers. Many of the workshop participants have stayed in contact with each other and continue to advocate for ocean governance. They include a public prosecutor in Sri Lanka's Ministry of Justice and the Principal Research Officer at the Institute of Marine Affairs of Trinidad and Tobago. All in all, there is considerable commitment worldwide to marine conservation, and it seems that nowadays, many more people are aware of the importance of the oceans and the sustainable management of marine resources than was the case only a few years ago.

Pressure from the grassroots

Marine conservation can be achieved in various ways: first and foremost, of course, through appropriate policy decisions, legislation, monitoring and sanctions However, policy-makers only tend to take action under pressure from civil society – and civil society can only exert pressure if the public is well-informed and has an understanding of the sustainable management of the marine and coastal environment.

The pressure that the public can exert should not be underestimated. For example, the IMO requirement for tankers to be fitted with double hulls was introduced, not least, as a result of massive public protests and media coverage, which became increasingly vehement over the years with each major tanker disaster. The fact that such disasters had to happen before action was taken should give us pause for thought. Farsighted planning for future sustainable development is therefore imperative.

4.24 > After the *Amoco Cadiz* oil tanker disaster off the coast of Brittany in March 1978, there were massive protests against oil pollution, as seen here in the French port of Brest. As a result of these protests, much more stringent tanker safety standards were introduced over the years.

Conclusion

How marine conservation can work

Despite the plethora of bad news about the state of the oceans, there are many positive examples which prove that it is possible to protect the seas and utilize marine resources sustainably. They include the decision by the International Maritime Organization (IMO) to introduce stricter emission limit values for shipping. Among other things, the maximum sulphur content of heavy fuel oil will be reduced from 2020, and in some sea areas, even more stringent regulations apply. These areas, known as ECAs, have been established for some of the busiest shipping routes where emissions from ships contribute significantly to coastal air pollution. They currently include the English Channel, the North Sea and the Baltic Sea, and the waters off the coast of the US and Canada.

Another success is the commercial whaling moratorium, which entered into force in 1986, spelling the end for the commercial hunting of the great whales. Although Iceland, Japan and Norway continue to hunt whales, the number of whales killed has decreased dramatically.

The fact that countries are able to reach agreement despite national self-interests is evidenced by the European Union's new Common Fisheries Policy (CFP). For many years, the EU's fishing fleet was far too large, but there was vehement opposition to any restriction on fishing from politicians keen not to lose votes, especially in structurally weak regions. Accordingly, the annual Total Allowable Catches (TACs) set by fisheries ministers for the various species were far higher than recommended by fishery scientists, resulting in the progressive overexploitation of many stocks in EU waters. With the new CFP, fishing in the EU will henceforth be based on maximum sustainable yield (MSY). The MSY is the maximum catch that can be taken from a species' stock over an indefinite period without jeopardizing that stock's productivity. The aim is to regulate fishing in a way which allows fish stocks to recover, enabling them to be fished at an optimal level in future. Although discussions on how the new fisheries policy should be implemented day-to-day are still ongoing, a start has been made.

If the marine environment is to be protected more effectively, based on the sustainable management of its resources, there must, in future, be better coordination between its conservation and diverse uses. Marine spatial planning (MSP) is an important tool in achieving this goal. MSP is a means of coordinating the various coastal and marine interests. Economic activities in the marine environment, e.g. fishing, offshore wind farm construction, dredging for marine aggregates (i.e. gravel and sand), shipping and oil production, must be balanced against other uses such as leisure and recreation and, not least, conservation. With its Federal Spatial Planning Act (Raumordnungsgesetz), Germany is a good example of how multiple interests can be reconciled through regulation.

As ever, marine conservation is most effective when the public itself takes action. A well-informed public with a good understanding of the marine environment can exert the necessary pressure to effect policy changes. To that end, however, it is often necessary to provide support, in the form of aid projects, so that people are able to take responsibility for the sustainable management of their environment. This capacity building is now a policy demand at the highest level and is enshrined in the United Nations' new Sustainable Development Goals (SDGs), a new sustainability agenda for the years to 2030. It is encouraging that with this agenda, marine conservation is, for the first time, a key global goal.

world ocean review
Living with the oceans. 2015

4

Sustainable Use of Our Oceans – Making Ideas Work

"Sustainability" has become one of today's inflationary terms and is therefore somewhat imprecise. Its meaning varies according to definition or context. Sustainability can only be achieved, however, if there is agreement on the concept and its meaning. Only then can a clear set of demands and appropriate policy measures be developed. This applies equally to sustainable management of onshore and offshore resources. This fourth edition of the *World Ocean Review* therefore attempts to build a bridge between the theory of sustainability and its practical application in science and policy-making. It shows how attempts are now being made in various scientific disciplines to develop viable hypotheses and models through which the findings of sustainability theoreticians can be translated into social, political and economic strategies with practical relevance. The implementation of these strategies is ultimately a matter for policy-makers, but private individuals, businesses and public institutions can make substantial contributions to sustainable development as well.

In the early days, the word "sustainability" was clearly defined. It originated in 18th century German silviculture: in 1713, chief mining administrator Hans Carl von Carlowitz published a treatise on forest management, entitled *Sylvicultura oeconomica* – the first publication ever to talk about "continual, consistent and sustainable use". At the time von Carlowitz coined the phrase, great quantities of wood were required for mining and the smelting of ores in many regions of Europe, resulting in progressive deforestation around many mining towns. An acute scarcity of this natural resource threatened to occur. By the early 18th century, wood had to be brought in by river from distant forests. Hans Carl von Carlowitz warned that people would suffer "great need" without wood and called for the forests to be preserved. The sustainable use of the forests was therefore promoted for purely economic reasons. This approach yet had little in common with the concept of nature conservation that has gained currency today.

With the Industrial Revolution, the concept of sustainability steadily receded into the background. Furthermore, as a consequence of the extreme privations suffered in two world wars, the Western industrialized nations, from the mid 20th century onwards, pursued one overriding political goal: to generate continuous economic growth and thus achieve prosperity for all. It was only in the early 1960s that there was growing criticism of this creed of growth and progress, for the damage increasingly inflicted on the environment as a result of the continual pursuit of economic growth was becoming impossible to ignore.

In the early 1980s, the United Nations (UN) established the World Commission on Environment and Development (WCED), whose purpose was to identify pathways towards several major objectives, among them alleviating poverty in the developing countries and halting environmental degradation. In 1987, the Commission published its report, entitled *Our Common Future*, also known as the Brundtland Report after Gro Harlem Brundtland, the then Prime Minister of Norway, who chaired the Commission. The Report initiated an important new debate about the role of sustainability but provided no practical guidance for policy-makers.

Overall conclusion

In the years that followed, sustainability researchers – basing their work on the Brundtland Report – developed the three-pillar model, which defines the three equally important dimensions – environmental, economic and social – of sustainability. However, it is clear that in many of the world's countries, economics continues to take precedence over the environmental and social dimensions. This has prompted experts in the ethics of sustainability to map out more specific pathways towards sustainable development. As one solution for the future, they propose the concept of "strong sustainability", whose aim is to preserve natural assets – known as natural capital – and protect them from ruthless exploitation. Strong sustainability does not view nature as a museum piece that must be preserved in a static state. Instead, it promotes the idea that renewable natural assets, such as fish stocks, can be exploited – but only to an extent that allows them to fully regenerate. Non-regenerative resources such as oil, with all their negative impacts, should therefore be replaced with renewables. Strong sustainability also calls for the restoration of depleted natural assets. It thus aims to reconcile the conservation of natural capital with its economic utilization. The constant natural capital rule (CNCR) is one attempt to put this concept in practice; according to the CNCR, natural capital should not decline over time but should be used responsibly and, above all, depleted natural resources should be replaced in full with natural capital of equal value.

Strong sustainability is intended to provide guidance for future policy decisions. However, sustainable use is only possible if people properly appreciate the significance and value of nature. In recent years, the notion of "natural capital" has often been replaced by the concept of "ecosystem services" in this context. With this approach, the services that nature can provide, now and in future – including marine ecosystem services – are categorized and evaluated individually. Four categories have now been defined: provisioning, supporting, regulating and cultural services. In relation to the marine environment, provisioning services include the production of fish stocks and the shipping lanes which nature provides free of charge. Cultural services include tourism but also traditions associated with the sea. The most important supporting service is primary production, notably the accumulation of marine biomass from phytoplankton through photosynthesis. "Regulating services" is scientists' blanket term for the basic biological, chemical and physical processes which take place in the oceans and benefit human well-being, such as the absorption of carbon dioxide.

Today, many of these services are at risk from overexploitation, pollution and climate change. Examples are the depletion of fish stocks through overfishing, and sea-level rise. Carbon dioxide emissions also pose a threat to the sea. A large amount of the carbon dioxide emitted into the atmosphere dissolves in seawater, causing gradual ocean acidification, with potentially devastating impacts on marine habitats such as coral reefs.

Coastal regions, many of which are densely populated, suffer disproportionately from these human-induced impacts. According to the United Nations, about 2.8 bil-

Overall conclusion

lion people – more than 40 per cent of the global population – now live in coastal cities. What's more, 13 of the world's 20 megacities with a population above 10 million are located on the coast, resulting in a high level of use and severe pollution of coastal waters in many cases. Eutrophication of coastal waters – caused by leaching of nutrients from agriculture – causes algal blooms and oxygen depletion in seawater and is a serious problem. The physical destruction of coastal habitats as a consequence of development, construction of embankments and discharge of pollutants continues, with wetlands, salt meadows, sand- and mudflats, coral reefs and mangrove forests particularly at risk.

In order to achieve sustainable use of marine habitats, researchers are now attempting, as a first step, to ascertain the current status of these habitats, for before targeted measures to improve them can be implemented, it is essential to have detailed knowledge of the extent to which a habitat is degraded and how close it is to its original healthy state. Various global programmes have therefore been established to collect comparative datasets. Researchers in the US, for example, have developed the global Ocean Health Index (OHI), which allows the status of diverse marine habitats to be compared. The OHI's scores are based on environmental factors such as biodiversity, but it also rates regions according to socioeconomic criteria, such as coastal livelihoods. However, general indices of this kind are not an adequate basis for more focused environmental policy-making: this requires specific target values or caps. In Europe, these targets are currently defined in the Marine Strategy Framework Directive (MSFD), which aims to achieve or maintain good marine environmental status by 2020. The Directive requires all of Europe's coastal states to develop and implement national marine strategies in order to achieve this goal.

It is thus apparent that the demand for comprehensive and sustainable use of the marine environment and therefore for good ocean governance must be directed at all stakeholders, including policy-makers. And indeed, a multitude of relevant institutions exists at the international level. However, in most cases, their policy-making remit only covers individual issues or sectors of relevance to the marine environment. Even in the United Nations, responsibility for marine matters is divided among several organizations and agencies. The International Maritime Organization (IMO), for example, is the United Nations' specialized agency responsible for regulating international shipping, while the International Seabed Authority (ISA) deals solely with the exploitation of marine minerals in international waters. There are also various major UN organizations whose agendas, although focusing mainly on other areas, have a tangential connection to the marine environment.

At regional level, too, a sectoral perspective on the marine environment currently prevails. Around 600 bilateral and multilateral treaties are now in force, each governing specific types of use within a given region. Due, perhaps, to the sheer number of agreements, there are few examples of genuinely well-functioning regional ocean governance. Problems are caused by vested interests, corruption and, not least, the lack of cooperation among the countries concerned. Efforts to protect the marine environment along Africa's Atlantic coast between Mauritania and South Africa, for example, as agreed in the Abidjan Convention, which entered into force in 1984, were quickly abandoned. A coordinated approach was impeded by civil wars in Côte d'Ivoire, Liberia and Sierra Leone and by a lack of technical equipment and funding. A concerted marine conservation effort by the signatory states has only recently resumed.

The division of the seas into separate zones makes it more difficult to develop and implement programmes for the sustainable management and conservation of the marine environment as a whole. For example, a distinction is currently made between the territorial sea, which forms part of the coastal state's sovereign territory, the exclusive economic zone, in which a coastal state has exclusive rights to exploit the natural resources and fish stocks, and the high seas (international waters). The high seas offer a multitude of freedoms with few restrictions, with every state having a right of access. However, many experts now recommend that the freedom of the seas be restricted in the interests of sustainable use.

The establishment of protected areas in international waters (the high seas), for example, is poorly regulated in the law of the sea. There is currently no institution in existence with powers to protect an international sea area from top to bottom; in other words, from the water surface to the seabed. Nor is there any legal framework in which states might reach a binding agreement to protect and refrain from using a specific area of the sea. Some coastal states have established protected areas in their national waters, but no such arrangements currently exist in the high seas.

Despite the many obstacles, there are various examples of well-functioning ocean governance: one is the system of Port State Control (PSC), which monitors compliance with specific UN conventions. It permits national port authorities to detain a ship if it fails to comply with the provisions of the relevant international conventions. The IMO's decision to impose more stringent limits on exhaust gas from ships is a positive example. Among other things, the sulphur content in heavy fuel oil is to be reduced worldwide by 2020. In addition, various sea areas – known as Emission Control Areas (ECAs) – have been defined in which more stringent regulations apply.

Another success is the commercial whaling moratorium, which entered into force in 1986, spelling the end for the commercial hunting of the great whales. Although Iceland, Japan and Norway continue to hunt whales, the number of whales killed has decreased dramatically.

The fact that countries are able to reach agreement despite national self-interests is evidenced by the European Union's new Common Fisheries Policy (CFP). For many years, the EU's fishing fleet was far too large, but there was vehement opposition to any restriction on fishing from politicians keen not to lose votes, especially in structurally weak regions. Consequently, the annual Total Allowable Catches (TACs) set by fisheries ministers for the various species were far higher than recommended by fishery scientists, resulting in the progressive overexploitation of many stocks in EU waters. With the new CFP, fishing in the EU will henceforth be based on maximum sustainable yield (MSY). The MSY is the maximum catch that can be taken from a species' stock over an indefinite period without jeopardizing that stock's productivity. The aim is to regulate fishing in a way which allows fish stocks to recover, enabling them to be fished at an optimal level in future. Although discussions on how the new fisheries policy should be implemented day-to-day are still ongoing, a start has been made.

If the marine environment is to be protected more effectively, based on the sustainable management of its resources, there must, in future, be better coordination between its conservation and diverse uses. Marine Spatial Planning (MSP) is an important tool in achieving this goal. Economic activities in the marine environment, e.g. fishing, offshore wind farm construction and oil production, must be balanced against other uses such as leisure and recreation and, not least, conservation. With its Federal Spatial Planning Act (Raumordnungsgesetz), Germany is a good example of how multiple interests can be reconciled through regulation.

As ever, marine conservation is most effective when the public itself takes action. A well-informed public with a good understanding of the marine environment can exert the necessary pressure to effect policy changes. To that end, however, it is often necessary to provide support so that people are able to take responsibility for the sustainable management of their environment. This capacity building is now a policy demand at the highest level and is enshrined in the United Nations' new Sustainable Development Goals (SDGs), a new global sustainability agenda for the years to 2030. It is encouraging that with this agenda, marine conservation is, for the first time, a key global goal.

In many cases, scientists can already make recommendations on how the marine environment can be better protected and used more sustainably. In other words, pathways towards more sustainable management have already been identified. Nonetheless, there are still too many vested interests, especially in the economic sphere. Short-sighted and short-term profit maximization often takes priority. Overexploitation of marine resources is viewed as the price to be paid for profits. Furthermore, the political structures in many coastal states are still too inefficient to protect these states' own marine resources and thus safeguard a sustainable future for our oceans.

Glossary

The Glossary explains the meaning of specialist terms which are particularly important for an understanding of the text but which cannot be defined in the individual chapters due to space constraints. Glossary terms are printed in bold in the body of the review, making them easy to identify.

Drop-in sessions: Open advice and consultation sessions – especially in a university or neighbourhood setting – which people can attend without an appointment. Generally, an advisor is available for a given period to discuss a specific topic.

Ecosystem: A community of living organisms of various species in conjunction with their non-living environment (e.g. rock, mineral soil, humidity and other environmental factors). "Ecosystem" is a neutral scientific concept, although in a political context, it is often used to mean valuable physiographic regions which deserve protection. Forests, coral reefs and the Wadden Sea are all examples of ecosystems.

Gross national income (GNI): The sum of the income generated by all residents in a nation from employment and assets in a given year, whether received in the country itself or abroad. Prior to 1999, the term "gross national product" (GNP) was generally used.

Marshall Plan: A US initiative to aid Europe's recovery after the Second World War and consisting of loans and supplies of food, goods and raw materials. Officially known as the European Recovery Program (ERP), it was named after its initiator, Secretary of State George C. Marshall. It began in autumn 1948 and ran for four years. By 1952, the US had provided around 13 billion US dollars in financial and material assistance to Europe – equivalent to around 120 billion US dollars today. The US's motives for initiating the programme were humanitarian, coupled with a desire to build a strong and united Europe capable of standing firm against the Eastern bloc and trading with the US.

Nominal capacity: The maximum output generated by an energy installation in the long term without causing damage to the installation or shortening its lifetime. The nominal capacity is always stated for motors or generators. Day to day, technical installations often operate below their nominal capacity, not least in order to protect them from wear or damage. Wind turbines generally only reach their nominal capacity on very windy days.

Rio+20: The United Nations Conference on Sustainable Development (UNCSD), which was held in Rio de Janeiro in 2012, exactly 20 years after the 1992 United Nations Conference on Environment and Development (UNCED), which also took place in Rio and is still known as the Rio Summit. In June 1992, representatives of 178 countries convened at the Rio Summit to discuss environmental and development issues for the 21st century. The Summit established sustainable development as the guiding vision for the international community. At Rio+20, the Sustainable Development Goals (SDGs) were elaborated and defined in more detail.

Seagrass meadows: A group of flowering plants which typically grow in sandy sediment in coastal waters and on tidal flats. They have long, herb-like fronds and thus resemble – but are unrelated to – the grasses that grow onshore. They are important habitats, providing young fish with food and protection from predators. Various species of fish lay their eggs directly on seagrass, so these meadows are often described as nurseries for fish. They are also a vital foraging ground for birds, such as Brent geese, during their autumn migration across Western Europe's Wadden Sea.

Seamounts: An undersea mountain, formed on the sea floor through volcanic activity and reaching at least 1000 metres while remaining beneath the ocean surface. Studies indicate that some seamounts host biotic communities with numerous rare or unique species. Seamounts exist in various areas of the sea, and there are thought to be many thousands of them worldwide.

Soil erosion: The wearing away of fertile and humus-rich topsoil by the natural physical forces of water and wind. Human communities can worsen soil erosion through their farming activities. After harvesting, harrowing and ploughing, for example, the soil is unprotected and erosion can easily occur. Deforestation can have a similar effect by leaving soil exposed. In the long term, soil erosion causes the loss of precious arable land.

United Nations Statistics Division (UNSD): United Nations (UN) division responsible for compiling and disseminating global statistical information, developing global standards and norms for statistical activities, and promoting cooperation between national statistical services. The UNSD's work is overseen by the United Nations Statistical Commission as the apex entity of the UN's and the world's statistical system.

Warsaw Pact: A Soviet-led political and military alliance, which existed from 1955 to 1991, between the USSR and several Eastern European countries as a counterbalance to the North Atlantic Treaty Organization (NATO). The founding treaty was signed in Warsaw in 1955 by the USSR, Albania, Bulgaria, Czechoslovakia, the German Democratic Republic, Hungary, Poland and Romania.

Contributors

Many experts have contributed their specialized knowledge to the compilation of the *World Ocean Review* in 2015. In particular, scientists working together on questions related to the development of our seas in the Cluster of Excellence "The Future Ocean" participated in the present work.

Erik van Doorn, researcher specializing in international law at Kiel University's Walther Schücking Institute for International Law. In recent years, his research has focused mainly on the United Nations Convention on the Law of the Sea and aspects of fishing in international waters. He studied at the Universities of Groningen, Utrecht and Tromsø, worked in the FAO Fisheries Department in Rome and was a legal assistant at the International Tribunal for the Law of the Sea in Hamburg.

Dr. René Friedland, biomathematician and expert in ecosystem modelling; member of the Coastal and Marine Management Group at the Leibniz Institute for Baltic Sea Research (IOW) in Warnemünde. His work focuses mainly on the status of the southwest Baltic and ways of achieving good environmental quality. To that end, he considers how the Baltic Sea's ecosystem evolves when external factors change, with particular reference to the climate and nutrient inputs. In recent years, he has conducted numerous simulations which have been validated by the current status of the Baltic Sea. From these studies, it is possible to determine the historical and largely undisrupted environmental status of the Baltic Sea and to estimate the range of possible future developments in this maritime region.

Dr. Uwe Jenisch, Honorary Professor for International Law of the Sea at Kiel University's Walther Schücking Institute for International Law and a member of the Cluster of Excellence "The Future Ocean". As an expert in administrative law, he has served in various German ministries since 1970, working on shipping, marine scientific research, maritime technology and the law of the sea. He was a member of the German delegation of maritime lawyers at the Third United Nations Conference on the Law of the Sea (UNCLOS III) and has lectured on the law of the sea at Kiel and Rostock Universities and the World Maritime University in Malmö. His current areas of interest are the law pertaining to deep-sea mining, the legal status of the Arctic, and maritime safety.

Dr. Ulrike Kronfeld-Goharani, physical oceanographer and interdisciplinary marine researcher at the Institute of Social Sciences at Kiel University. Her fields of research include ocean governance, maritime security, sustainable development, ecological security, marine conservation, conflicts over the use of marine resources, and adaptation and transformation of coastal and maritime regions in response to changing needs and more intensive competition.

Stephan Lutter, marine ecologist and zoologist for the World Wide Fund for Nature (WWF) Germany and WWF International, with a particular interest in the protection of the marine environment. He also monitors and documents the global development of ocean governance. As an expert in international marine conservation and marine protected areas, he represents WWF in numerous international bodies, including those relating to the Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR) and the North East Atlantic Fisheries Commission, and EU working groups on the implementation of Natura 2000 and the Marine Strategy Framework Directive. He played a key role in the designation of the Charlie-Gibbs Marine Protected Area in the high seas of the North Atlantic and many other offshore marine protected areas. His work also focuses on the protection of endangered species, habitats and biotic communities in the high seas and deep sea through regulation of fishing, the extractive industries and shipping.

Prof. Dr. Konrad Ott, philosopher and Professor for Philosophy and Ethics of the Environment at Kiel University. In recent years, his research has focused primarily on "strong sustainability" issues, the practical dimensions of nature and biodiversity conservation, climate change, water resources, agriculture and remediation. After completing a doctorate at the University of Leipzig, he collaborated with Barbara Skorupinski on the research project "Technology Assessment and Ethics" at the University of Zurich from 1996 to 1999. In 1997, he took up an endowed professorship in the Mathematics and Science Faculty at the University of Greifswald, where he taught environmental ethics on the interdisciplinary Landscape Ecology and Nature Conservation programme until 2012. He was a member of the German Advisory Council on the Environment (SRU) from 2008 to 2012.

Prof. Dr. Martin Quaas, economist at the University of Kiel and leader of the research group "Fisheries and Overfishing/Living Resources" in the Cluster of Excellence "The Future Ocean". His specialist areas are environmental, resource and ecological economics. One goal of his research is the development of new fisheries management strategies and new market-based fisheries policy instruments that promote sustainability in this sector.

Prof. Dr. Katrin Rehdanz, economist at the Kiel Institute for the World Economy and Associate Professor of Environmental and Resource Economics at the University of Kiel. She has a particular interest in environmental valuation. She conducts analyses of attitudes to natural services as a basis for computable general equilibrium modelling, the aim being to ensure that more account is taken of trade-offs between use and conservation in decision-making on ecosystem services.

Dr. Wilfried Rickels, economist at the Kiel Institute for the World Economy. His research focuses on climate change (climate engineering) and sustainable development. In relation to the latter, he is particularly interested in sustainability strategies for the ocean and in opportunities and methods for measuring marine development, with particular reference to the UN Sustainable Development Goals.

Dr. Jörn O. Schmidt, fisheries biologist at the University of Kiel in the working group "Sustainable Fisheries" in the Cluster of Excellence "The Future Ocean". He is the German member on the Science Committee of the International Council for the Exploration of the Sea, where he represents Germany's scientific interests in relation to fisheries research. Together with two colleagues from Denmark and the US, he also leads a working group that investigates fishery management using coupled ecological-economic models.

Prof. Dr. Martin Visbeck, physical oceanographer at the GEOMAR Helmholtz Centre for Ocean Research, Professor at the University of Kiel and Spokesperson of the Kiel Cluster of Excellence "The Future Ocean". His current research is concerned with ocean circulation and climate dynamics in the Atlantic and the development of strategies for sustainable management of the seas. He is a member of various international advisory bodies, including the World Climate Research Programme's Joint Scientific Committee, and chairs the German Committee Future Earth.

Bibliography

Chapter 1 – Concepts for a better world

Bertram, C. & K. Rehdanz, 2013: On the environmental effectiveness of the EU Marine Strategy Framework Directive. Marine Policy, 38: 25–40.

Bertram, C., T. Dworak, S. Görlitz, E. Interwies & K. Rehdanz, 2014: Cost-benefit analysis in the context of the EU Marine Strategy Framework Directive: The case of Germany. Marine Policy, 43: 307–312.

Brander, L.M., D. Narita, K. Rehdanz & R.S.J. Tol, 2014: The economic impacts of ocean acidification. In: Paulo, A.L.D, P.A.L.D Nunes, P. Kumar & T. Dedeurwaerdere (Ed.): Handbook on the Economics of Biodiversity and Ecosystem Services, Edward Elgar: 78–92.

Costanza, R., R. d'Arge, R. de Groot, S. Farberk, M. Grasso, B. Hannon, K. Limburg, S. Naeem, R.V. O'Neill, J. Paruelo, R.G. Raskin, P. Sutton & M. van den Belt, 1997: The value of the world's ecosystem services and natural capital. Nature, 387: 253–260.

Döring, R. & U. Hampicke (Ed.), 2004: Ökonomische Rationalität und praktische Vernunft – Gerechtigkeit, Ökologische Ökonomie und Naturschutz. Verlag Königshausen und Neumann.

Duxbury, J. & S. Dickinson, 2007: Principles for sustainable governance of the coastal zone: In the context of coastal disasters. Ecological Economics, 63: 319–330.

O'Connor, M., 2000: Natural capital. Environmental Valuation in Europe, Policy Research Brief, 3. Cambridge Research for the Environment.

Ott, K. & R. Döring, 2008: Theorie und Praxis starker Nachhaltigkeit. Metropolis-Verlag.

Ott, K., B. Muraca & C. Baatz, 2011. Strong sustainability as a frame for sustainability communication. In: J. Godemann & G. Michelsen (Ed.): Sustainability Communication: Interdisciplinary Perspectives and Theoretical Foundations.

Schultz, J., F. Brand, J. Kopfmüller & K. Ott, 2008: Building a 'theory of sustainable development': two salient conceptions within the German discourse. International Journal of Environment and Sustainable Development, 7, 4.

Solow, R., 1993: An almost practical step toward sustainability. Resources Policy, 9: 162–172.

United Nations General Assembly, 2012: The future we want – Resolution adopted by the General Assembly on 27 July 2012 – 66/288.

Visbeck, M., U. Kronfeld-Goharani, B. Neumann, W. Rickels, J. Schmidt, E. van Doorn, N. Matz-Lück & A. Proelss, 2014: A Sustainable Development Goal for the Ocean and Coasts: Global ocean challenges benefit from regional initiatives supporting globally coordinated solutions. Marine Policy, 49: 87–89.

Visbeck, M., U. Kronfeld-Goharani, B. Neumann, W. Rickels, J. Schmidt, E. van Doorn, N. Matz-Lück, K. Ott & M.F. Quaas, 2014: Securing blue wealth: The need for a special sustainable development goal for the ocean and coasts. Marine Policy, 48: 184–191.

Ziegler, R. & K. Ott, 2011: The quality of sustainability science: a philosophical perspective. Sustainability: Science, Practice, & Policy, 7, 1.

www.gov.uk/government/organisations/department-for-environment-food-rural-affairs

Chapter 2 – How the sea serves us

Alfsen, K.H. & M. Greaker, 2007: From natural resources and environmental accounting to construction of indicators for sustainable development. Ecological Economics, 61: 600–610.

Baillie, J.E.M., C. Hilton-Taylor & S.N. Stuart (Ed.), 2004. 2004 IUCN Red List of Threatened Species. A Global Species Assessment. IUCN.

Balmford, A., A. Bruner, P. Cooper, R. Costanza, S. Farber, R.E. Green, M. Jenkins, P. Jefferiss, V. Jessamy, J. Madden, K. Munro, N. Myers, S. Naeem, J. Paavola, M. Rayment, S. Rosendo, J. Roughgarden, K. Trumper & R.K. Turner, 2002: Economic Reasons for Conserving Wild Nature. Science, 297: 950–953.

Brander, L.M., K. Rehdanz, R.S.J. Tol & P.J.H. van Beukering, 2012: The Economic Impact of Ocean Acidification on Coral Reefs. Climate Change Economics, 3, 1.

Baumgärtner, S. & M. Quaas, 2010: What is sustainability economics? Ecological Economics, 69: 445–450.

Böhringer, C. & P.E.P. Jochem, 2007: Measuring the immeasurable – A survey of sustainability indices. Ecological Economics 63: 1–8.

Burke, L., K. Reytar, M. Spalding & A. Perry, 2011: Reefs at risk – revisted. World Resources Institute.

Costanza, R., F. Andrade, P. Antunes, M. van den Belt, D. Boersma, D.F. Boesch, F. Catarino, S. Hanna, K. Limburg, B. Low, M. Molitor, J.G. Pereira, S. Rayner, R. Santos, J. Wilson & M. Young, 1998: Principles for Sustainable Governance of the Oceans. Science, 281: 198–199.

Costanza, R., R. de Groot, P. Sutton, S. van der Ploeg, S.J. Anderson, I. Kubiszewski, S. Farber & R.K. Turner, 2014: Changes in the global value of ecosystem services. Global Environmental Change, 26: 152–158.

Costanza, R., F. Andrade, P. Antunes, M. van den Belt, D. Boesch, D. Boersma, F. Catarino, S. Hanna, K. Limburg, B. Low, M. Molitor, J.G. Pereira, S. Rayner, R. Santos, J. Wilson & M. Young, 1999: Ecological economics and sustainable governance of the oceans – Commentary. Ecological Economics, 31: 171–187.

European Academies Science Advisory Council, 2015: Marine sustainability in an age of changing oceans and seas. European Bureau for Conservation and Development.

Giri, C., E. Ochieng, L.L. Tieszen, Z. Zhu, A. Singh, T. Loveland, J. Masek & N. Duke, 2011: Status and distribution of mangrove forests of the world using earth observation satellite data. Global Ecology and Biogeography, 20: 154–159.

Global Ocean Commission, 2014: From Decline to Recovery – A Rescue Package for the Global Ocean.

Halpern, B.S., C. Longo, D. Hardy, K.L. McLeod, J.F. Samhouri, S.K. Katona, K. Kleisner, S.E. Lester, J. O'Leary, M. Ranelletti, A.A. Rosenberg, C. Scarborough, E.R. Selig, B.D. Best, D.R. Brumbaugh, F.S. Chapin, L.B. Crowder, K.L. Daly, S.C. Doney, C. Elfes, M.J. Fogarty, S.D. Gaines, K.I. Jacobsen, L.B. Karrer, H.M. Leslie, E. Neeley, D. Pauly, S. Polasky, B. Ris, K. St. Martin, G.S. Stone, U.R. Sumaila & D. Zeller, 2012: An index to assess the health and benefits of the global ocean. Nature, 488: 615–622.

Helcom, 2010: Ecosystem Health of the Baltic Sea 2003–2007: Helcom Initial Holistic Assessment. Baltic Sea Environment Proceedings, 122.

Kenneth, J.A., P. Dasgupta, L.H. Goulder, K.J. Mumford & K. Oleson, 2012: Sustainability and the measurement of wealth. Environment and Development Economics, 17: 317–353.

Hughes, S., A. Yau, L. Max, N. Petrovic, F. Davenport, M. Marshall, T.R. McClanahan, E.H. Allison & J.E. Cinner, 2012: A framework to assess national level vulnerability from the perspective of food security: The case of coral reef fisheries. Environmental Science & Policy, 23: 95–108.

IOC/UNESCO, IMO, FAO, UNDP, 2011: A Blueprint for Ocean and Coastal Sustainability. IOC/UNESCO.

Kildow, J.T. & A. McIlgorm, 2010: The importance of estimating the contribution of the oceans to national economies. Marine Policy, 34: 367–374.

Quaas, M.F., R. Froese, H. Herwartz, T. Requate, J.O. Schmidt & R.Voss, 2012: Fishing industry borrows from natural capital at high shadow interest rates. Ecological Economics, 82: 45–52.

Rickels, W., M.F. Quaas & M. Visbeck, 2014: How healthy is the human-ocean system? Environmental Research Letters, 9.

Steffen, W., K. Richardson, J. Rockström, S.E. Cornell, I. Fetzer, E.M. Bennett, R. Biggs, S.R. Carpenter, W. de Vries, C.A. de Wit, C. Folke, D. Gerten, J. Heinke, G.M. Mace, L.M. Persson, V. Ramanathan, B. Reyers & S. Sörlin, 2015: Planetary boundaries: Guiding human development on a changing planet. Science, 347.

Stojanovic, T.A. & C.J.Q. Farmer, 2013: The development of world oceans & coasts and concepts of sustainability. Marine Policy, 42: 157–165.

TEEB, 2009: The Economics of Ecosystems and Biodiversity for National and International Policy Makers.

United Nations, 2014: Chapter 5 – Sea/Air Interactions. World Ocean Assessment.

United Nations, 2014: Chapter 6 – Primary Production, Cycling of Nutrients, Surface Layer and Plankton. World Ocean Assessment.

United Nations, 2014: Chapter 8 – Aesthetic, cultural, religious and spiritual ecosystem services derived from the marine environment. World Ocean Assessment.

United Nations, 2014: Chapter 9 – Conclusions on major ecosystem services other than provisioning services. World Ocean Assessment.

United Nations, 2014: Chapter 27 – Tourism and recreation. World Ocean Assessment.

United Nations, 2014: Chapter 34 – Gradients in Marine Biodiversity. World Ocean Assessment.

United Nations, 2014: Chapter 35 – Extent of assessment of marine biological diversity. World Ocean Assessment.

United Nations, 2014: Chapter 56 – Overall assessment of human impact on the oceans. World Ocean Assessment.

United Nations, 2014: Chapter 57 – Overall value of the oceans to humans. World Ocean Assessment.

United Nations Conference on Trade and Development, 2013: Review of maritime transport.

Wissenschaftlicher Beirat der Bundesregierung Globale Umweltveränderungen, 2014: Zivilisatorischer Fortschritt innerhalb planetarischer Leitplanken – ein Beitrag zur SDG-Debatte. Politikpapier, 8.

Xing, Q., M. Gao, X. Gao, L. Tosi, F.G. Schmitt, Y. Zhang, P. Shi, J. Wei & Y. Luo, 2014: Progressive eutrophication behind the world-largest super floating macroalgal blooms in the Yellow Sea. Biogeosciences Discussion, 11: 7029–7054.

www.oceanhealthindex.org

www.stockholmresilience.org

Chapter 3 – Politics and the oceans

European Commission, 2013: Mapping and Assessment of Ecosystems and their Services – An analytical framework for ecosystem assessments under Action 5 of the EU Biodiversity Strategy to 2020. Discussion Paper.

Global Ocean Commission, 2014: From Decline to Recovery – A Rescue Package for the Global Ocean.

Haines-Young, R. & M. Potschin, 2013: Common International Classification of Ecosystem Services (CICES): Consultation on Version 4, August–December 2012.

IOC/UNESCO, IMO, FAO, UNDP, 2011: A Blueprint for Ocean and Coastal Sustainability. IOC/UNESCO.

PEMSEA, 2013: People. Partners. Progress. PEMSEA Accomplishment Report 2011–2013. Partnerships in Environmental Management for the Seas of East Asia.

Staub, C., W. Ott, F. Heusi, G. Klingler, A. Jenny, M. Häcki & A. Hauser, 2011: Indicators for Ecosystem Goods and Services: Framework, methodology and recommendations for a welfare-related environmental reporting. Environmental Studies, 1102.

UNEP/Nairobi Convention Secretariat, WIOMSA, 2009: The Status of Municipal Wastewater Management in the Western Indian Ocean Region. UNEP.

Wissenschaftlicher Beirat der Bundesregierung Globale Umweltveränderungen (WBGU), 2013: Welt im Wandel – Menschheitserbe Meer, Hauptgutachten.

http://abidjanconvention.org

http://iea.uoregon.edu

www.imo.org

www.unep.org/regionalseas/about/background/default.asp

Chapter 4 – Hope for the oceans

Beisheim, M., 2015: Reviewing the Post-2015 Sustainable Development Goals and Partnerships – A Proposal for a Multi-level Review at the High-level Political Forum. SWP Research Paper, Stiftung Wissenschaft und Politik, German Institute for International and Security Affairs.

Beisheim, M., H. Løkken, N. aus dem Moore, L. Pintér & W. Rickels, 2015: Measuring Sustainable Development: How can Science Contribute to Realizing the SDGs? SWP Working Paper, Stiftung Wissenschaft und Politik, German Institute for International and Security Affairs.

Bundesamt für Seeschifffahrt und Hydrographie, 2009: Anlage zur Verordnung über die Raumordnung in der deutschen ausschließlichen Wirtschaftszone in der Nordsee (AWZ Nordsee-ROV). Bundesgesetzblatt 61, 1.

Coastal Zone Management Authority and Institute, 2015: Belize Integrated Coastal Zone Management Plan.

Ehler, C. & F. Douvere, 2009: Marine Spatial Planning: a step-by-step approach toward ecosystem-based management. Intergovernmental Oceanographic Commission and Man and the Biosphere Programme. IOC Manual and Guides 53, ICAM Dossier 6.

European Wind Energy Association, 2015: The European offshore wind industry – key trends and statistics 2014.

Global Ocean Commission, 2015: Proposed Elements of Indicators for SDG Goal 14 – Oceans, Seas and Marine Resources. A contribution by the Global Ocean Commission to the Post-2015 Intergovernmental Negotiation.

Greenpeace, 2011: Die Internationale Walfang-Kommission (IWC) – Geschichte und Ausblick.

ICSU/ISSC, 2015: Review of the Sustainable Development Goals: The Science Perspective.

International Energy Agency, 2014: CO_2-Emissions from fuel combustion – highlights.

International Energy Agency, 2014: Key world energy statistics.

Marine Management Organisation, 2015: South inshore and south offshore marine plan areas – Statement of Public Participation: February 2015.

Sustainable Development Solutions Network, 2015: Indicators and a Monitoring Framework for Sustainable Development Goals – Launching a data revolution for the SDGs. Revised working draft for consultation.

United Nations, 2014: Millenniums-Entwicklungsziele – Bericht 2014.

https://iwc.int/home

www.coastalzonebelize.org

www.gwec.net/global-figures/global-offshore/

www.isa.org.jm/

Table of figures

Cover and p. 2: Claudius Diemer, albedo39 Satellitenbildwerkstatt, Köln (www.albedo39.de); p. 7 from top: © Stuart Franklin/Magnum Photos/Agentur Focus; © Stuart Franklin/Magnum Photos/Agentur Focus; Alex MacLean/Trunk Archive; plainpicture/NaturePL; Claudius Diemer, albedo39 Satellitenbildwerkstatt, Köln (www.albedo39.de); p. 8/9: © Stuart Franklin/Magnum Photos/Agentur Focus; fig. 1.1: bpk/Staatliche Kunstsammlungen Dresden/Herbert Boswank; fig. 1.2: Nixon, Harry F./Minnesota Historical Society; fig. 1.3: Massimo Ripani/SIME/Schapowalow; fig. 1.4: Library of Congress, Prints and Photographs Division, Washington, D.C./Reproduction Number: LC-DIG-cwpbh-02223; fig. 1.5: ap/dpa/picture alliance/Süddeutsche Zeitung Photo; fig. 1.6: maribus; fig. 1.7: Andrew Biraj; fig. 1.8: Daniel Hohlfeld/fotolia.com; fig. 1.9: mauritius images/Henryk Tomasz Kaiser; fig. 1.10: http://de.wikipedia.org/wiki/Coalbrookdale (status: october 2015); fig. 1.11: mauritius images/Alamy; fig. 1.12: after Costanza et al.; fig. 1.13: Costanza et al.; fig. 1.14: Mario A. Blanco; fig. 1.15: Christian Kerber/laif; fig. 1.16: Ingetje Tadros/Getty Images; fig. 1.17: interTopics/UPI Photo/eyevine; p. 36/37: © Stuart Franklin/Magnum Photos/Agentur Focus; fig. 2.1: akg-images/Album/Oronoz; fig. 2.2: Imaginechina/Corbis; fig. 2.3: UNCTAD, Clarkson Research Services; fig. 2.4: after Stockholm Resilience Centre; fig. 2.5: Science Photo Library/Steve Gschmeissner/Getty Images; fig. 2.6: after Raworth/Oxfam; p. 44/45: maribus; fig. 2.7: © Bruno Barbey/Magnum Photos/Agentur Focus; fig. 2.8: Jakob Demus, Wien; fig. 2.9: Belga/face to face; fig. 2.10: Behrooz Sangani; fig. 2.11: © Steffen Binke/SeaPics.com; fig. 2.12: UN/WOA, IFAW; fig. 2.13: after Meincke et al.; fig. 2.14: Natalie Fobes/Getty Images; fig. 2.15: after Folegot/Quiet-Oceans; fig. 2.16: © Alexander Semenov/Science Photo Library/Agentur Focus; fig. 2.17: Frans Lanting/Corbis; fig. 2.18: UPPA/Photoshot; fig. 2.19: after Cózar et al.; fig. 2.20: Georgette Douwma/nature picture library; fig. 2.21: World Resources Institute; fig. 2.22: World Resources Institute; fig. 2.23: Giri et al.; fig. 2.24: © Manfred Bail/SeaPics.com; fig. 2.25: NASA/Goddard Space Flight Center Scientific Visualization Studio; fig. 2.26: Jolan Kieschke; fig. 2.27: Friedland/IOW, maribus; p. 74/75: Alex MacLean/Trunk Archive; fig. 3.1: Pierre Gleizes/Greenpeace; fig. 3.2: after Proelß; fig. 3.3: UN Photo/Milton Grant; fig. 3.4: Kronfeld-Goharani/Geomar; fig. 3.5: mauritius images/Jinny Goodman/Alamy; fig. 3.6: hgm-press/bnps; fig. 3.7: Jesco Denzel; fig. 3.8: Global Ocean Commission; fig. 3.9: mauritius images/David Shale/nature picture library; fig. 3.10: Reuters/John Javellana (Philippines); fig. 3.11: © Doug Perrine/SeaPics.com; fig. 3.12: www.paul-langrock.de; fig. 3.13: Bundeswehr/Matthias Döhler; p. 96/97: plainpicture/NaturePL; fig. 4.1: UN; fig. 4.2: UN; fig. 4.3: KARI/ESA; fig. 4.4: ullstein bild/Africa Media Online; fig. 4.5: Tim Rainger/Clean Media NZ; fig. 4.6: Nick Cobbing; fig. 4.7: EPA; fig. 4.8: Aufwind-Luftbilder/Visum; fig. 4.9: PhotoXPress/Visum; fig. 4.10: Natalie Behring/Panos Pictures/Visum; fig. 4.11: IEA; fig. 4.12: IEA; fig. 4.13: maribus; fig. 4.14: Jens Köhler/WWF; fig. 4.15: www.siemens.com/presse; fig. 4.16: Mark Schuurman/Buiten-beeld/Getty Images; fig. 4.17: GWEC; fig. 4.18: EWEA; fig. 4.19: after BSH; fig. 4.20: Detlev Gehring/TenneT; fig. 4.21: after CZMAI; fig. 4.22: after CZMAI; fig. 4.23: Kimberley Coole/Lonely Planet/Getty Images; fig. 4.24: Alain Dejean/Sygma/Corbis

Index

Page numbers printed in **bold** draw attention to passages within the text which are especially important for an understanding of the concept in question.

Abbreviations

ACs Advisory Councils

AIS Automatic Identification System

B_{MSY} Biomass maximum sustainable yield

CBD Convention on Biological Diversity

CCAMLR Commission for the Conservation of Antarctic Marine Living Resources

CCLME Canary Current Large Marine Ecosystem

CFP Common Fisheries Policy

CITES Convention on International Trade in Endangered Species of Wild Fauna and Flora

CLCS Commission on the Limits of the Continental Shelf

CMS Convention on Migratory Species

CNCR Constant Natural Capital Rule

COL Consortium for Ocean Leadership

COS Center for Oceans Solutions

CSI Cetacean Society International

CZM Coastal Zone Management

CZMAI Coastal Zone Management Authority and Institute

DESA Department of Economic and Social Affairs

DOALOS Division for Ocean Affairs and the Law of the Sea

DSCC Deep Sea Conservation Coalition

ECAs Emission Control Areas

EEZ Exclusive economic zone

EMSEA European Marine Science Educators Association

FAO Food and Agriculture Organization

GEF Global Environment Facility

GESAMP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection

GOBI Global Ocean Biodiversity Initiative

GOF Global Ocean Forum

GIS Geo-informations system

HELCOM Helsinki Commission

HLPF High-Level Political Forum on Sustainable Development

ICES International Council for the Exploration of the Sea

ICJ International Court of Justice

ICM Integrated Coastal Management

ICP Informal Consultative Process (on Oceans and the Law of the Sea)

ICRI International Coral Reef Initiative

ICSF International Collective in Support of Fishworkers

ICSU International Council for Science

ICSU/SCOR ICSU Scientific Committee on Ocean Research

ICSU/SCAR ICSU Scientific Committee on Antarctic Research

IEA International Energy Agency

ILO International Labour Organization

IMBER Integrated Marine Biogeochemistry and Ecosystem Research

IMO International Maritime Organization

IOC Intergovernmental Oceanographic Commission

IOC CARIBE IOC Sub-Commission for the Caribbean and Adjacent Regions

IOC WESTPAC IOC Sub-Commission for the Western Pacific

IOC AFRICA IOC Sub-Commission for Africa and the Adjacent Island States

IOI International Ocean Institute

IPSO International Programme on the State of the Ocean

ISA International Seabed Authority

ISSF Information System on Small-Scale Fisheries

ITLOS International Tribunal for the Law of the Sea

IUCN International Union for Conservation of Nature

IWC International Whaling Commission

LC London Convention

LME Large Marine Ecosystem

LP London Protocol

MARPOL International Convention for the Prevention of Marine Pollution from Ships

MBI Monaco Blue Initiative

MDGs Millennium Development Goals

MA Millennium Ecosystem Assessment

MEA Multilateral Environmental Agreement

MMO Marine Management Organisation

MPA Marine Protected Area

MSFD Marine Strategy Framework Directive

MSP Marine Spatial Planning

MSY Maximum sustainable yield

MW Megawatt

NEAFC North East Atlantic Fisheries Commission

NGO Non-governmental organization

NOAA National Oceanic and Atmospheric Administration

NTZ No Take Zone

OCR Ocean Conservation Research

OHI Ocean Health Index

OSPAR Oslo and Paris Convention

OWG Open Working Group

PacMara Pacific Marine Analysis and Research Association

PEMSEA Partnerships in Environmental Management for the Seas of East Asia

ppm parts per million

PSC Port State Control

RFMOs Regional Fisheries Management Organisations

RSP Regional Seas Programme

SDGs Sustainable Development Goals

SOI Sustainable Ocean Initiative

SOLAS International Convention for the Safety of Life at Sea

TBTI Too Big To Ignore

TEV Total Economic Value

TWh Terawatt-hour

UN United Nations

UNDG UN Development Group

UNDP UN Development Programme

UNEP UN Environment Programme

UNESCO UN Educational, Scientific and Cultural Organization

UN-OHRLLS UN Office of the High Representative for the Least Developed Countries, Landlocked Developing Countries and Small Island Developing States

UNGA United Nations General Assembly

UNSG Secretary-General of the UN

UNWTO United Nations World Tourism Organization

WCED World Commission on Environment and Development

WMO World Meteorological Organization

WOC World Ocean Council

WTA willingness to accept

WTP willingness to pay

WWF World Wide Fund

Partners

The Future Ocean: The Kiel-based Cluster of Excellence brings together marine scientists, earth scientists, economists, medical scientists, mathematicians, lawyers and social scientists to share their knowledge and engage in joint interdisciplinary research on climate and ocean change. The research group comprises more than 200 scientists from 7 faculties of the Christian-Albrechts-University of Kiel (CAU), the GEOMAR Helmholtz Centre for Ocean Research in Kiel, the Institute for World Economy (IfW) and the Muthesius University of Fine Arts.

IOI: The International Ocean Institute is a non-profit organization founded by Professor Elisabeth Mann Borgese in 1972. It consists of a network of operational centres located all over the world. Its headquarters are in Malta. The IOI advocates the peaceful and sustainable use of the oceans.

mare: The bimonthly German-language magazine mare, which focuses on the topic of the sea, was founded by Nikolaus Gelpke in Hamburg in 1997. mare's mission is to raise the public's awareness of the importance of the sea as a living, economic and cultural space. Besides the magazine, which has received numerous awards for its high-quality reporting and photographs, its publisher mareverlag also produces a number of fiction and non-fiction titles twice a year.

Acknowledgements

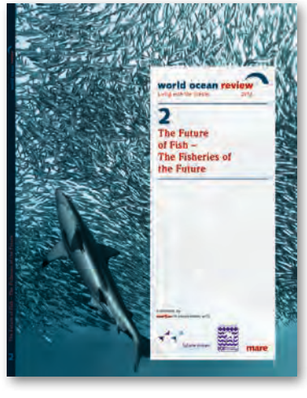
Producing a publication like the *World Ocean Review* is a collective effort which relies on the dedication and commitment of a large number of people. I would therefore like to first express my thanks to all the participating scientists for their contributions to this review. I am also most grateful to the organizational team of the Cluster of Excellence "The Future Ocean" for ensuring a smooth and uninterrupted communication process and for working so hard behind the scenes.

I further wish to express my particular appreciation to the scientific journalist Tim Schröder, who gave structure to the individual texts and ensured that they could be read and enjoyed by scientists and the general public alike. My sincere thanks also go to designer Anna Boucsein, photo editor Petra Koßmann, text editor Dimitri Ladischensky, and last but not least Jan Lehmköster, the project manager at maribus, who nurtured the *World Ocean Review* from the beginning and whose leadership helped to shape it into the publication it is today.

Nikolaus Gelpke
Managing Director of maribus gGmbH

Following *World Ocean Reviews* have already been published and can be ordered free of charge at: www.worldoceanreview.com

WOR 3, 2014
Marine Ressources – Opportunities and Risks



WOR 2, 2013
The Future of Fish – The Fisheries of the Future

WOR 1, 2010
Living with the oceans – a report on the state of the world's oceans

Publication details

Project manager: Jan Lehmköster
Editing and text: Tim Schröder
Copy editing: Dimitri Ladischensky
Coordinator at the Cluster of Excellence: Sigrid Keiser
Design and typesetting: Anna Boucsein, Andrea Best
Photo-editing: Petra Koßmann
Graphics: Walther-Maria Scheid
Printing: Ruksaldruck GmbH & Co. KG
Paper: Balance Silk, FSC-certified

ISBN 978-3-86648-253-1
Published by: maribus gGmbH, Pickhuben 2, 20457 Hamburg, Germany

www.maribus.com